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Automated meteorological and oceanographic data collection and distribution in support of C4I, weapons, and remote sensing systems

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AUTOMATED METEOROLOGICAL AND OCEANOGRAPHIC DATA COLLECTION AND DISTRIBUTION IN SUPPORT OF C4I, WEAPONS, AND REMOTE SENSING SYSTEMS

by

William Hughes Nisley II

September 2000

Thesis Advisor:	Kenneth L. Davidson
Co-Advisor:	Andreas K. Goroch

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AUTOMATED METEOROLOGICAL AND OCEANOGRAPHIC DATA COLLECTION AND DISTRIBUTION IN SUPPORT OF C4I, WEAPONS, AND REMOTE SENSING SYSTEMS

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Submitted in partial fulfillment of the
requirements for the degree of

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September 2000

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On-scene characterization of the battlespace environment is critical toward providing the warfighter with an effective understanding of the environment and its impact on weapon systems and sensors and requires the rapid acquisition and dissemination of on-scene meteorological and oceanographic (METOC) measurements. The current practice of manually observing and recording METOC data is labor intensive, outdated, and no longer capable of satisfying the requirements for higher temporal and spatial observations.

This study reviews the current methodology to characterize the battlespace environment, summarizes relevant Navy needs, and describes the results of integrating a prototype small combatant integrated METOC system (SCIMS) developed by the Naval Postgraduate School, with a prototype data processing and distribution system (Weather Viewer) developed by SPAWARSYSCEN San Diego.

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The study concludes with particular recommendations for updating and improving the system of environmental data collection, processing, utilization, and archival.

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A great number of people contributed to the successful completion of this thesis. I am particularly indebted to my advisor, Dr. Ken Davidson, for supporting and facilitating my goal to pursue an issue of direct fleet application. It has also been my good fortune to work with my co-advisor, Dr. Andreas Goroch (Naval Research Laboratory-Monterey), whose expertise in data collection and insights in computer programming were critical to the success of the at-sea demonstration and subsequent development of SMART Log. Their professional guidance and friendship will serve me well in the years to come.

Other individuals deserving special thanks include: Dr. Ed Harrison (Space and Naval Warfare Systems Command, PMW-185), who approved the funding support for this project, Mr. Bob Calland (PMW-185), who provided the software interface used to demonstrate the capability to automate several of the processes necessary to format and disseminate on-scene METOC data; Mr. Dick Lind, who was responsible for installing the SCIMS system on board the R/V Pt. Sur and provided invaluable advice in setting up the data acquisition equipment; Mr. Stewart Lamerdin of Moss Landing Marine Laboratory for assisting with the communications interfaces on board the R/V Pt. Sur; Professors Curt Collins and Peter Guest who supported the at-sea testing as concurrent fulfillment of OC-3570 course requirements; LCDR Brian Connon, who's thesis laid the groundwork for developing new and innovative tools for relaying critical METOC data ashore and; Ms. Eva Anderson, who provided the administrative and travel support required by this project.

I would also like to thank the many professors who make the METOC program at the Naval Postgraduate School such a worthwhile experience, and my classmates for their friendship and humor during the constant challenges inherent in our curriculum.

Most importantly, I wish to acknowledge the efforts of my wife Patricia, whose unwavering support is the foundation for my success as a naval officer.

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I. INTRODUCTION

A primary focus of the Commander, Naval Meteorology and Oceanography Command (CNMOC) Strategic Plan (1999) is enhanced warfighting capabilities. Such enhancement is achievable only by fully characterizing the battlespace environment for the warfighter in terms that enable optimal employment of systems and platforms. The critical factor in realizing such an outcome is obtaining an accurate description of the environment whether it is in, above or on the open ocean, or a littoral region. Recent operations in the Persian Gulf (Desert Shield/Desert Storm), Arabian Sea (Somalia), and the Adriatic (Bosnia) clearly demonstrate that enhanced capabilities can be enabled through the fusion of (a) techniques to rapidly describe the environment and (b) the relaying of tactically relevant information via automated command, control, communications, computers and intelligence (C4I) capabilities. This effort requires continuous data collection from on-scene as well as remote sensors and integrating the results into tactical decision aids and/or directly into weapon systems and their delivery platforms.

The Oceanographer of the Navy articulated the importance of assessing the environment in a position statement titled "Navy Position on The Importance of Ocean Observations to Naval Operations" (CNO (N096), 1999):

> Successful Naval operations require mastery of the complex maritime environment, anytime, anywhere, to maximize operational effectiveness and minimize impact on platforms, weapons, and sensors. Our recent involvement in Kosovo demonstrated the critical importance and impact of the environment on all phases of military operations, from planning and surveillance to precision engagement and battle damage assessment. **Observations in the open ocean and littoral, from beneath the sea floor to the top of the atmosphere, provide information critical to all Naval and joint warfare missions.** The consequence of high quality ocean observations, taken more often and in more locations around the world, will be yield improvements in mission planning and tactical decision aids, thus enabling the warfighter to make more informed and higher confidence decisions before and during operations.

The requirement to increase automation of meteorological and oceanographic (METOC) data collection and its dissemination cannot be overemphasized. The reduction of available collection platforms and manpower dictates a greater reliance on

high-speed communications and a corresponding reduction in manual methods for acquiring METOC data.

An acquisition program for development of a shipboard METOC data collection and distribution system (MORIAH) is underway to provide such capabilities on surface ships. This is a summary of the results of MORIAH system testing and related METOC data collection efforts on board a research vessel, the R/V Pt. Sur, during two underway periods: 1-4, and 5-8 FEB 2000. For this testing, a prototype MORIAH system, Small Combatant Integrated Meteorological System (SCIMS) (Figure 1-1), was installed at the forward, port side location on Pt. Sur's flying bridge. A second very similarly instrumented tower was installed on the starboard side to support other data collection efforts. During the first underway period of 01-04 February, the SCIMS system was operated in an automated mode for data collection only. During the second period, SCIMS was used with client software to acquire and also to encode and transmit surface and upper air data collected on board the Pt Sur. Figure 1-2 shows ship tracks during each of these periods. During the second period from 05-08 February, encoded data were successfully transmitted to METCAST servers at Fleet Numerical Meteorology and Oceanography Center (FNMOC), Monterey, CA. The observations were stored in the tactical environmental data server (TEDS) database at FNMOC and successfully received aboard the R/V Pt. Sur. The successful transmission and retrieval of METOC data collected on board R/V Pt. Sur demonstrated the ability to disseminate real-time METOC observations to fleet users on a global scale.

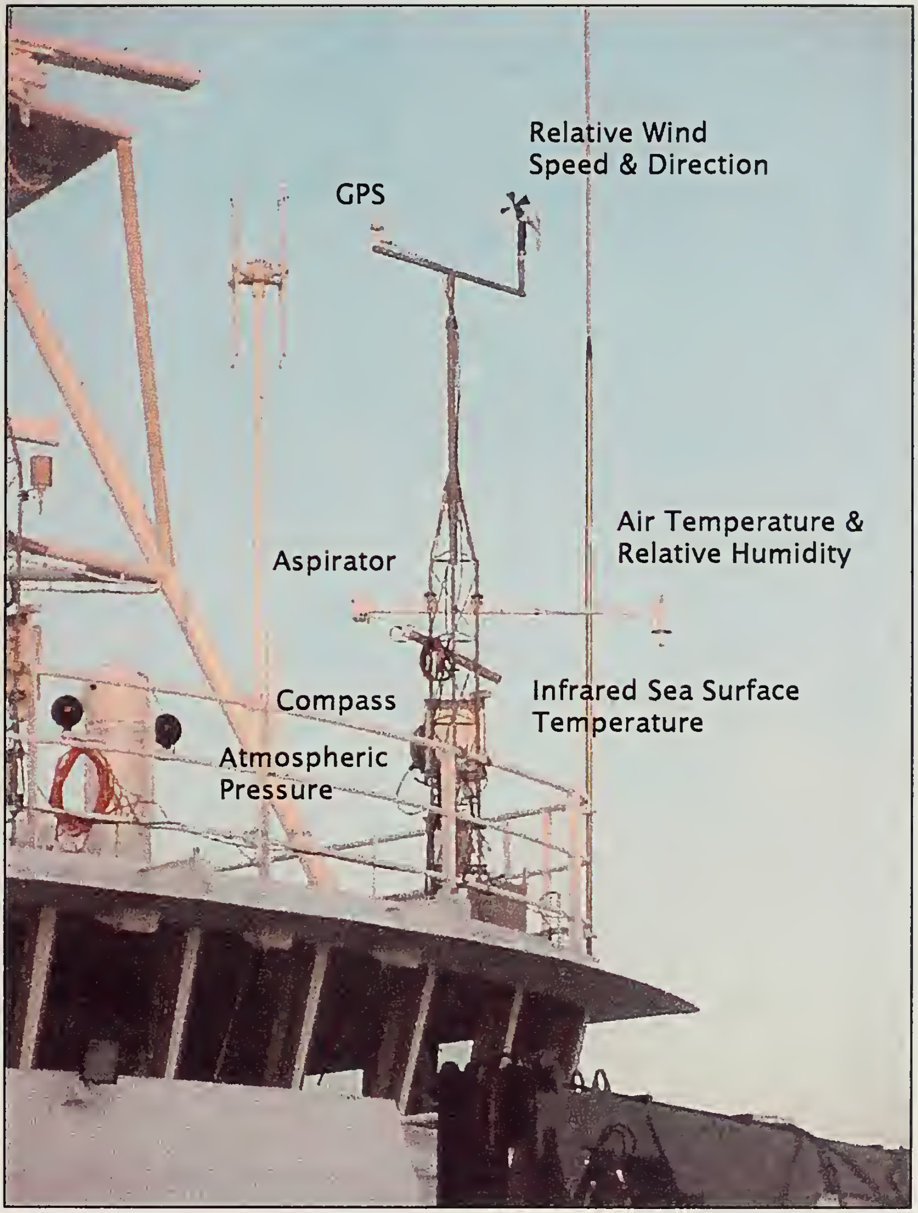

Figure 1-1 NPS SCIMS tower installed on board R/V Pt. Sur.

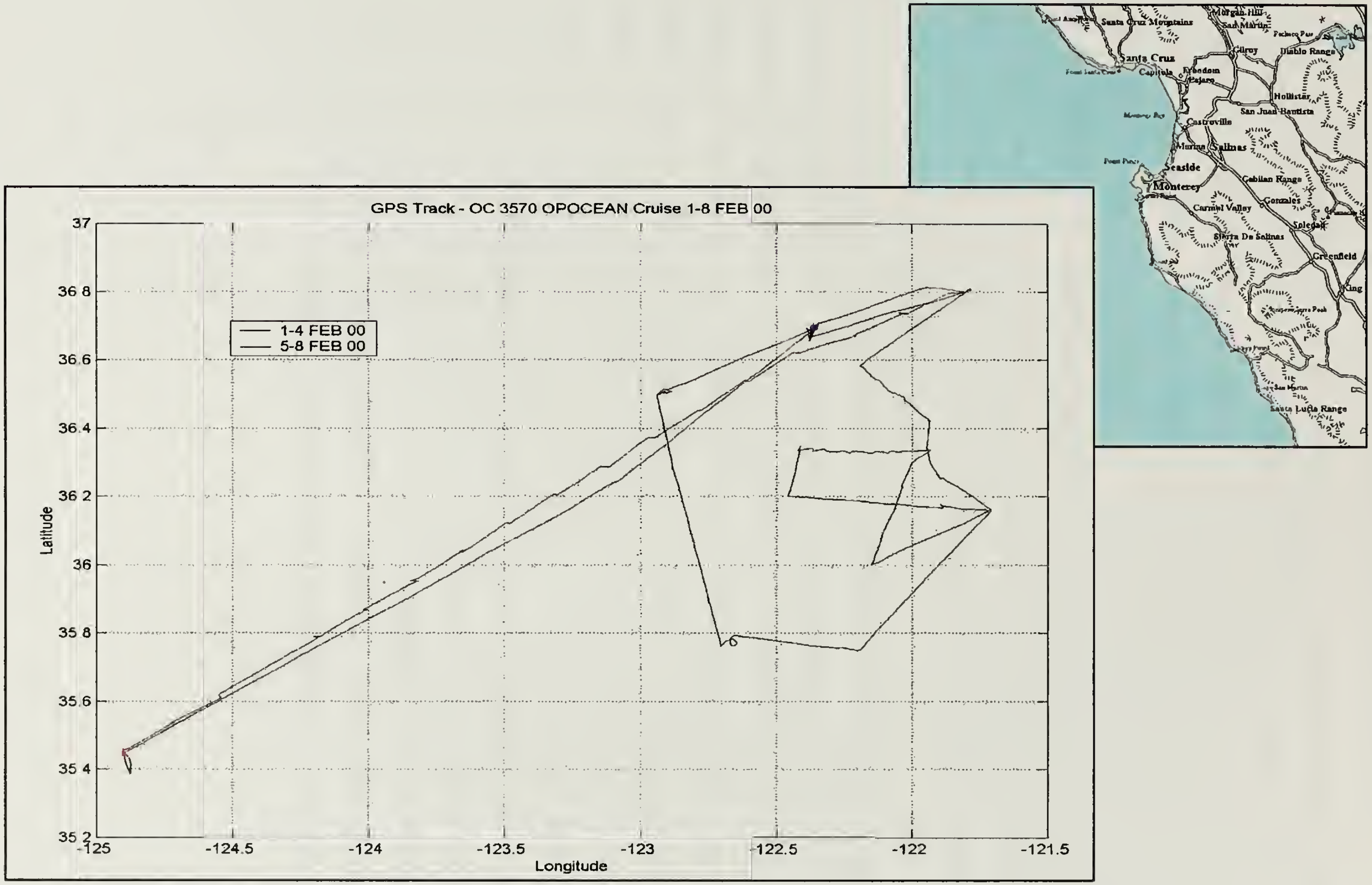

Figure 1-2 Pt. Sur navigation tracks for 1-4 and 5-8 FEB 00 in the general vicinity of the Central California / Monterey Bay coastal region. Both tracks begin and end at Moss Landing, CA.

II. PURPOSE AND OBJECTIVES

The primary purpose of this project was to demonstrate improvements related to increased use of current technologies in acquiring real-time METOC data and, subsequent relay of processed data to fleet users in support of naval warfare and tactical decision aids (TDAs). The real-time data are those required to describe sensible weather as well as air-sea flux parameters. The project demonstration also provided combined developmental and operational testing of WxViewer (WxV) Client software in direct support of Space and Naval Warfare Systems Command (SPAWARSYSCOM) PMW 185. Initial evaluation indicates that underway testing was highly successful and all test objectives were substantially attained.

There were four main objectives of this project. The first objective was to collect and display METOC data using automated instrumentation. This involved the design, testing and installation of METOC equipment for operation at sea, aboard a research vessel, and the design and operation of an automated data acquisition, processing and storage system. The second objective was to digitally encode and transmit WMO coded reports to FNMOC. This involved the design and coding of software to process METOC observations, format them for storage and for transmission, and transmit the data over available communications channels to FNMOC. The third objective was to acquire WMO coded data and other numerical weather products while underway via METCAST. This required Internet based access to FNMOC for retrieval of selected data and products. WMO coded upper air reports retrieved via METCAST were then used for the fourth objective, which was to decode acquired data for use in TDAs, i.e. AREPS.

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III. BACKGROUND

A. MORIAH PROGRAM DESCRIPTION

As published in the operational requirements document (ORD), MORIAH represents the consolidation and combination of two existing programs: the New Digital Wind Measuring and Indicating System (NDWMIS) and the Shipboard Meteorological and Oceanographic Observing System (SMOOS) Replacement (SMOOS(R)).

The consolidated program is co-sponsored by Chief of Naval Operations (CNO) N85, N86, N88, and N096 and executed by the Aviation Launch and Recovery Equipment (ALRE) Program Manager, Naval Air Systems Command (NAVAIRSYSCOM) PMA 251. METOC expertise is provided by the METOC Program Manager, SPAWARSYSCOM PMW 185 and AEGIS Program expertise is provided by Program Executive Officer (PEO) for Theater Air Defense-Surface Combatants (TAD-SC), Naval Sea Systems Command (NAVSEASYSCOM) PMS 400. CNO (N8) approved a Memorandum of Agreement between the sponsors in February 1998 (CNO, 1998). In addition to the various officials cited above, Naval Postgraduate School (NPS) and Naval Research Laboratory Monterey (NRL-MRY) are coordinating system validation and verification (V&V) support to PMW-185 and participate in hardware development and related system engineering efforts with Johns Hopkins University-Applied Physics Laboratory (JHU-APL). Additional technical support was provided by FNMOC for METCAST related testing.

The MORIAH METOC data collection prototype system has been deployed as an integral part of the SEAWASP system on board USS Anzio (CG-68) and USS Cape St. George (CG-71). PMS-400 sponsored SEAWASP to acquire continuous METOC measurements in an effort to assess real-time radar propagation conditions and for optimization of AEGIS weapon system configurations (JHU-APL, 1997). JHU-APL designed, built, and installed the SEAWASP systems in USS Anzio (ANZ) and USS Cape St. George (CSG) systems.

B. DESCRIPTION OF THE BATTLESPACE ENVIRONMENT AND THE NEED FOR CONTINUOUS MEASUREMENTS

Characterizing the battlespace requires a full understanding of the effects of atmospheric and oceanographic conditions on elements of our own forces, our allies, and on the enemy. The approaches for achieving such an understanding lead to the requirement to accurately and continuously measure and quantify variables impacting platforms, weapons, and sensors.

The extent by which current aircraft and weapon system performance can be enhanced or degraded by weather and oceanographic conditions has dramatically increased the need to measure the environment. Current technologies combined with supersonic ordnance delivery continues to minimize reaction times such that enabling weapon and sensor system configurations to exploit favorable conditions or to mitigate the negative effects of unfavorable METOC conditions is central, toward the safe and efficient execution of all naval warfare missions.

Operational mesoscale models at NRL and FNMOC require data not only at a higher spatial resolution, but also at a much higher frequency to achieve the accuracy required to generate forecasts at much finer scales (i.e. less than 1km spatial scale and less than 1hr time scale) in support of littoral operations. The current mesoscale models generally operate with an approximately one minute time step. The forecasts are generally output every hour to 3 hours, depending on the specifics of the model resolution, for a period from 3 to 48 hours in the future. Initialization data are collected within six-hour intervals for processing by three dimensional optimal interpolation techniques. (Hodur, 1996)

The NOWCAST data assimilation / fusion system currently under development at NRL (Cook, 2000), is designed to provide short term/short range predictions in the period of 0-2 hours with a grid resolution on the order of 1km by sub-hourly (15-20 minutes) processing of model output and observations. The model initialization requirements will be critically dependent on high frequency data input with the general requirement of 5-minute observations of wind, temperature and moisture This is particularly important in coastal regions where local conditions are extremely variable, and a high density of

observations is necessary for understanding the local environmental picture (Goroch, 2000).

Recent investigations into the temporal and spatial variations in temperature and humidity profiles illuminates the problem of forecasting sensor performance based on single profiles versus range dependant propagation modeling. Use of a single profile invokes an assumption of lateral homogeneity with regard to atmospheric conditions and may result in errors in two-dimensional propagation loss ranging from 4-8dB for distances less than 30km, to greater than 10dB for extended ranges out to 90km. Furthermore, the error introduced through the use of standard (climatological mean) atmospheric profiles can be as high 20dB. Goldhirsh and Dockery (1998) found that these errors occur at least ten percent of the time.

Additionally, it can be shown that while shore based data is valuable for over-land targeting, it is not a valid substitute for computing sensor performance within the maritime regime. Figure 3-1 illustrates the difference in vertical atmospheric profiles observed at Kuwait International Airport, and reported by USS Caron approximately 150nm east of Bahrain, at sea in the Persian Gulf. Simple visual inspection indicates significantly difference air-mass regimes. Kuwait is dominated by a well mixed boundary layer, 1800m deep, compared to the shallow but stable boundary layer approximately 300m deep at USS Caron's position. A complete analysis of 169 profiles collected during the U.S. Navy exercise SHAREM-115 conducted in April 1996 showed large propagation errors over the central Persian Gulf when derived from a single profile. (Brooks, 1998)

The importance of in-situ data collection and dissemination is further demonstrated by the high degree of variability observed in sensor measurements as well as in derived parameter values used in TDAs. Operational SEAWASP obtained data presented by Sadanaga (Figures 3-2, 3-3 and 3-4 (all times are GMT)) illustrate the spatial and temporal variability of evaporative duct heights (EDH). EDH was derived from continuous real-time, wind, air and sea temperature, and humidity measurements taken aboard ANZ and CSG in the Persian Gulf on 16 November 1998. From 0000Z to 0400Z, SEAWASP measurements and EDH estimates yielded similar refractive conditions

for both ships with duct heights of approximately 7m. However, shortly after 0400Z, the Anzio SEAWASP system did not acquire reliable information for almost 2 hours (0600Z)[1]. During this period, CSGs SEAWASP system continued to acquire and process reliable near-continuous information that showed calculated duct heights increasing to approximately 25m. (Sadanaga, 1999)

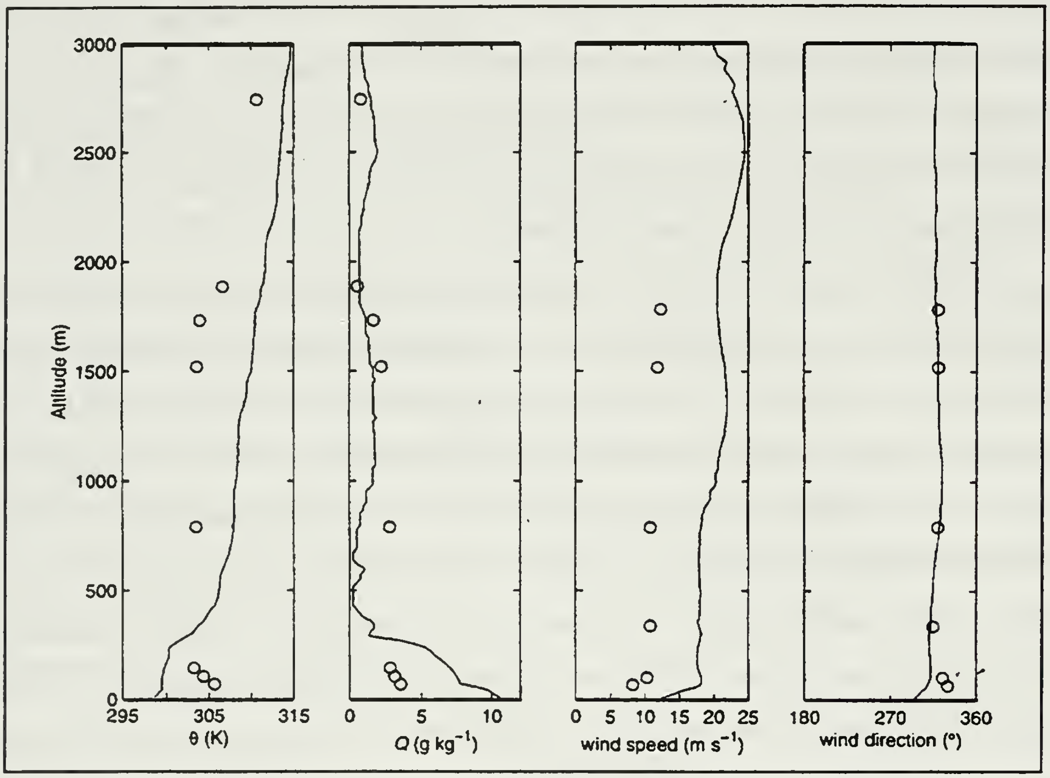


Figure 3-1 Profiles of potential temperature (θ), total water mixing ratio (Q), wind speed, and wind direction taken at Kuwait International Airport at 1200 UTC (O) and from a rawinsonde observation taken on board USS Caron at 26°09′N 053°06′E at 1330 UT (—) on 28 APR 1996 (from Brooks, 1998).

[1] Note: This loss of data does not indicate a system failure but was caused by data reliability screening algorithms within SEAWASP. Sadanaga (1999) presents an analysis of this data.

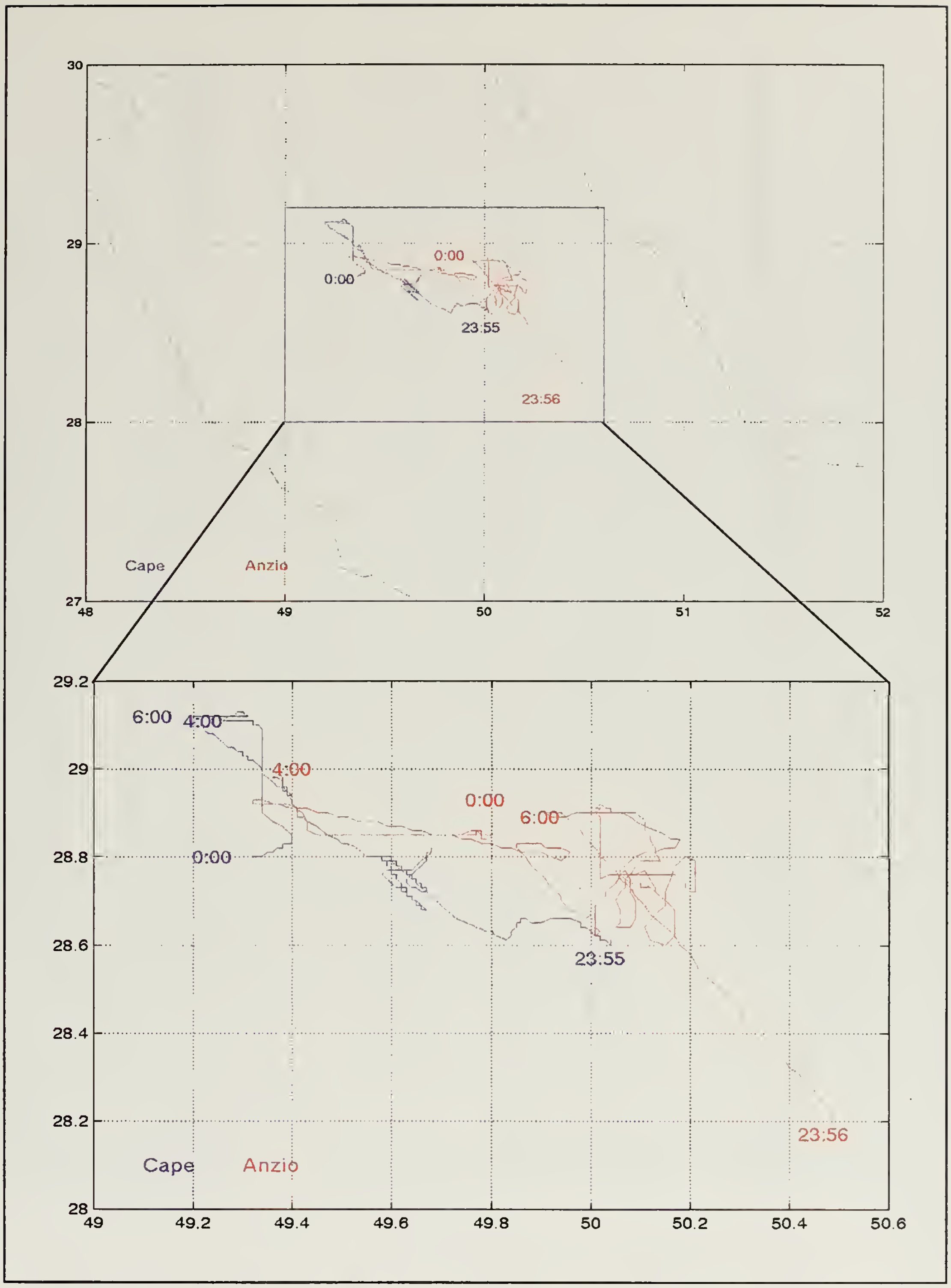


Figure 3-2 **Navigation track data for USS Anzio and USS Cape St. George in the Arabian Gulf on 16 November 1998 (from Sadanaga, 1999).**

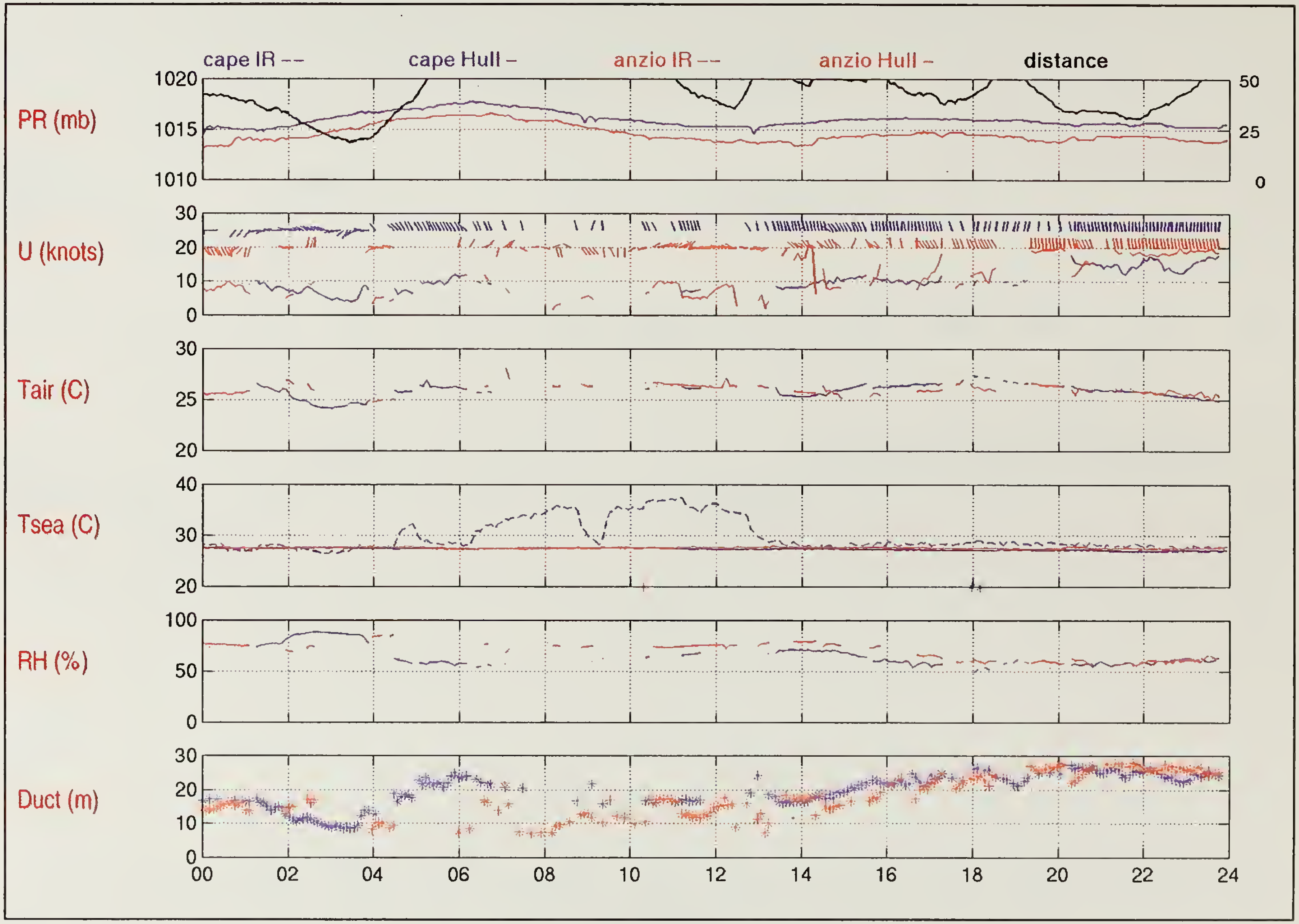


Figure 3-3 In-situ measurements taken on board USS Anzio (red) and USS Cape St George (blue) on 16NOV98 (from Sadanaga, 1999).

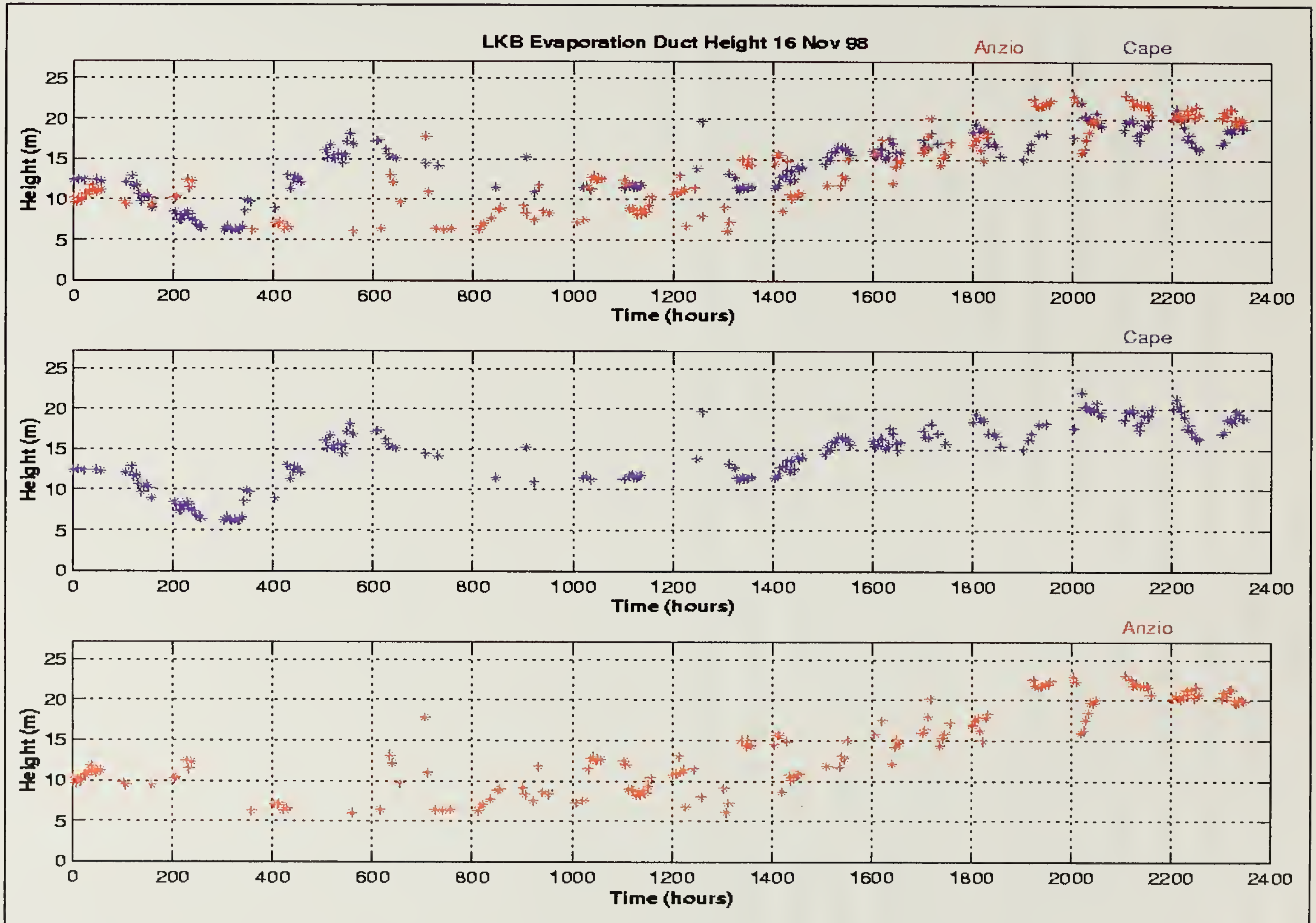
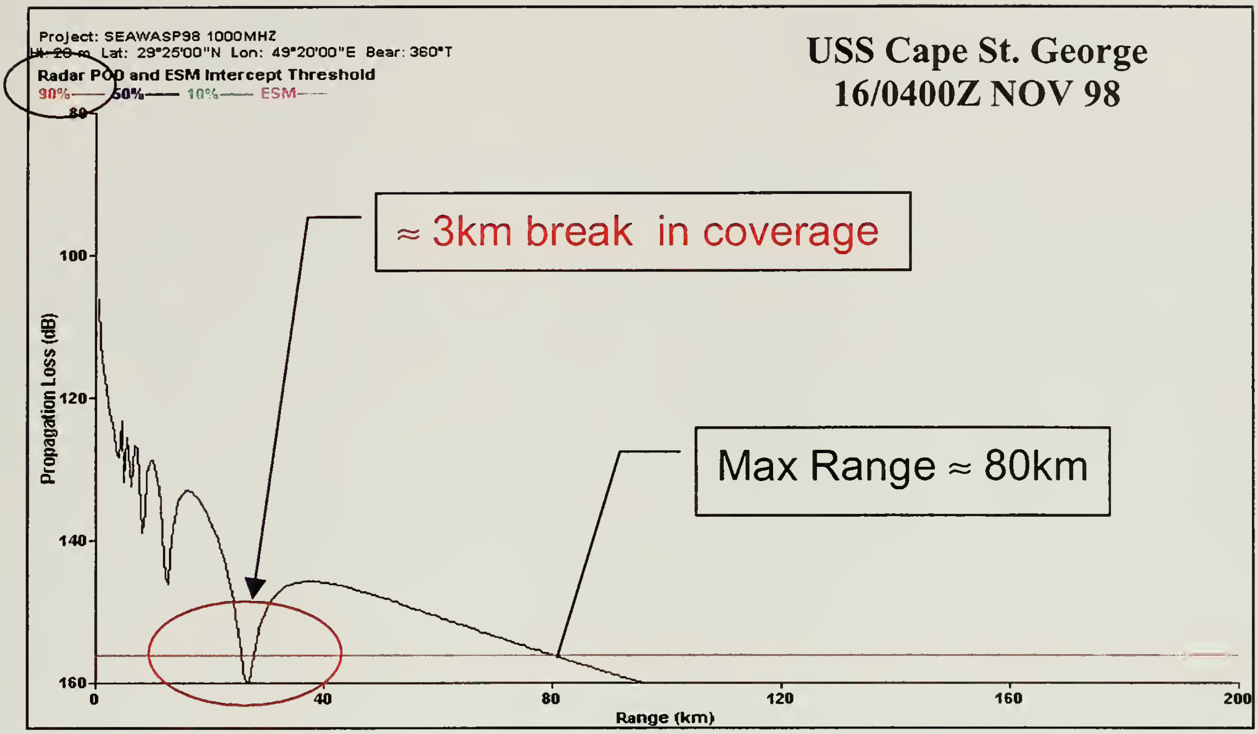


Figure 3-4 In-situ evaporative duct heights for USS Anzio (red) and USS CapeStGeorge (blue) on 16NOV98 (from Sadanaga, 1999).

Figure 3-3 further illustrates the spatial variability of METOC parameters measured as a function of the physical separation between ANZ and CSG. Throughout the 24-hour period, the distance between ANZ and CSG varied from a minimum of 20km to greater than 50km. Near 0400Z, a frontal boundary passed over CSG. EDH decreased with the approach of the front and then increased to a maximum near 0600Z as relative humidity dropped sharply with frontal passage. As seen in Figure 3-2, at 0400Z, ANZ tracked back to the east-southeast and remained ahead of the front until near 1000Z when the front finally overtook ANZs position.

The significance of this time series is the large variation of EDH in both time and space and the impact on tactics and weapon system performance. The difference is further quantified via TDA outputs for CSG at 0400Z and 0600Z. Figure 3-5 shows an increase in detection threshold from intermittent coverage out to 80km, to continuous coverage out to 110km. This 30km increase in detection translates to a potential 87 seconds of additional detection/warning time against an incoming target at Mach 1 ($\approx$ 344 m/s) velocity.



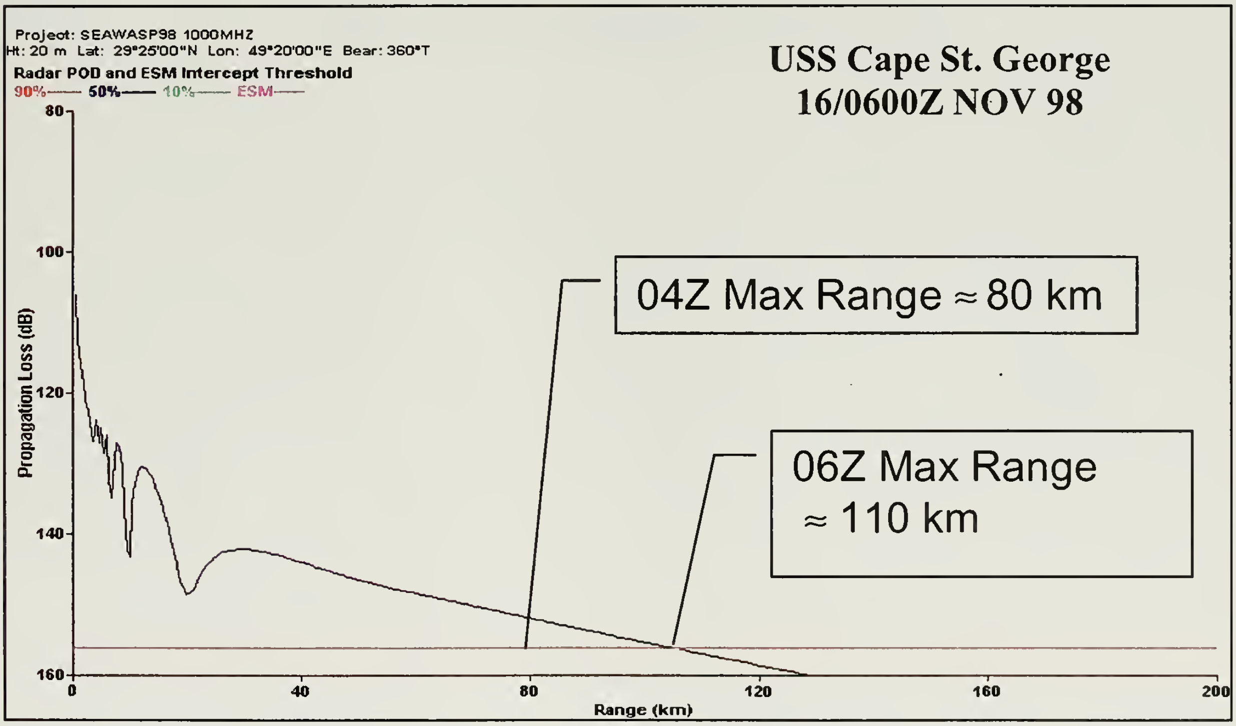


Figure 3-5 **AREPS propagation loss diagrams for a simulated 1000kHz radar at 20m (after Sadanada, 1999).**

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IV. ACQUISITION EQUIPMENT AND METOC SENSORS

A. NPS SCIMS TOWER

The METOC measurement system (SCIMS tower Figure 1-1) deployed for evaluation on the Pt. Sur was developed by NPS staff. This same tower was used on a previous evaluation of METOC data dissemination that was carried out on board USS Juneau (LPD-10) in April 1999, Connon (1999). SCIMS sensors are listed in Table 4-1.

Parameter Measured / Obtained	Sensor System
Air Temperature	Rotronic® Air Temperature and Relative Humidity Probe, Model MP-101A
Atmospheric Relative Humidity	Rotronic® Air Temperature and Relative Humidity Probe, Model MP-101A
Wind Direction and Speed	R.M. Young® Wind Direction and Speed System
Barometric Pressure	AIR® Digital Barometer, Model DB-1A
Sea Surface Temperature	Everest® Infrared Sea-Surface Temperature Sensor, Model 4000.4GL
Vessel Heading	Precision Navigation® Magnetic Compass, Model TCM-2
Vessel Position	Trimble® Geostationary Positioning System (GPS) Receiver, Model SV6

Table 4-1 NPS SCIMS sensors.

The tested SCIMS system is more advanced than that available for most shipboard METOC data collection. Currently, only CV/CVN, LHA/LHD, and LCC/AGF class ships are configured with SMOOS systems that provide automated data collection sensors for acquiring pressure, temperature, and wind data. All other platforms are limited to manual observation and measurement of primary METOC elements.

B. SCIMS/MORIAH ACQUISITION SYSTEM

A Campbell Scientific, Inc.® (CSI) CRX-10 data-logger and associated software was used to acquire continuously measured data. The CSI software was programmed to acquire sensor data every 15 seconds and compute one minute and five minute averaged data records. The data-logger also collected GPS data every 15 seconds and one and five minute GPS records were vector averaged to provide position information for each measurement record. An RS-232 serial interface provided the connectivity between the CRX-10 and laptop computer. Locally developed programs, written in MS Visual Basic 6.0®, were used to format the data for use by remote displays and to archive the acquired data.. The major impact of using MORIAH type acquisition systems is the availability of automated METOC measurements every 60 seconds compared to manual measurements every 60 minutes.

The SCIMS / WxViewer network (Figures 4-1 and 4-2) was composed entirely of commercial off-the-shelf (COTS) hardware and software. The system was designed to automatically retrieve data from the SCIMS tower, operate the CSI and WxV software, display measurements at various sites throughout the ship, transmit and retrieve data to and from shore sites and, execute tactical decisions aids and other support programs.

Because of the limited nature of the test, a static network configuration was used that did not require a network server or software. A 10base-T network hub allowed each of the three laptops to share files. This arrangement demonstrated the ability to distribute both raw and processed data to remote displays. Table 4-2 lists the components of the SCIMS network.

Figure 4-1 SCIMS / WxViewer network installed on R/V Pt. Sur. Displays include current weather, JMV fields retrieved via METCAST, and WxViewer Client synoptic observation input screen.

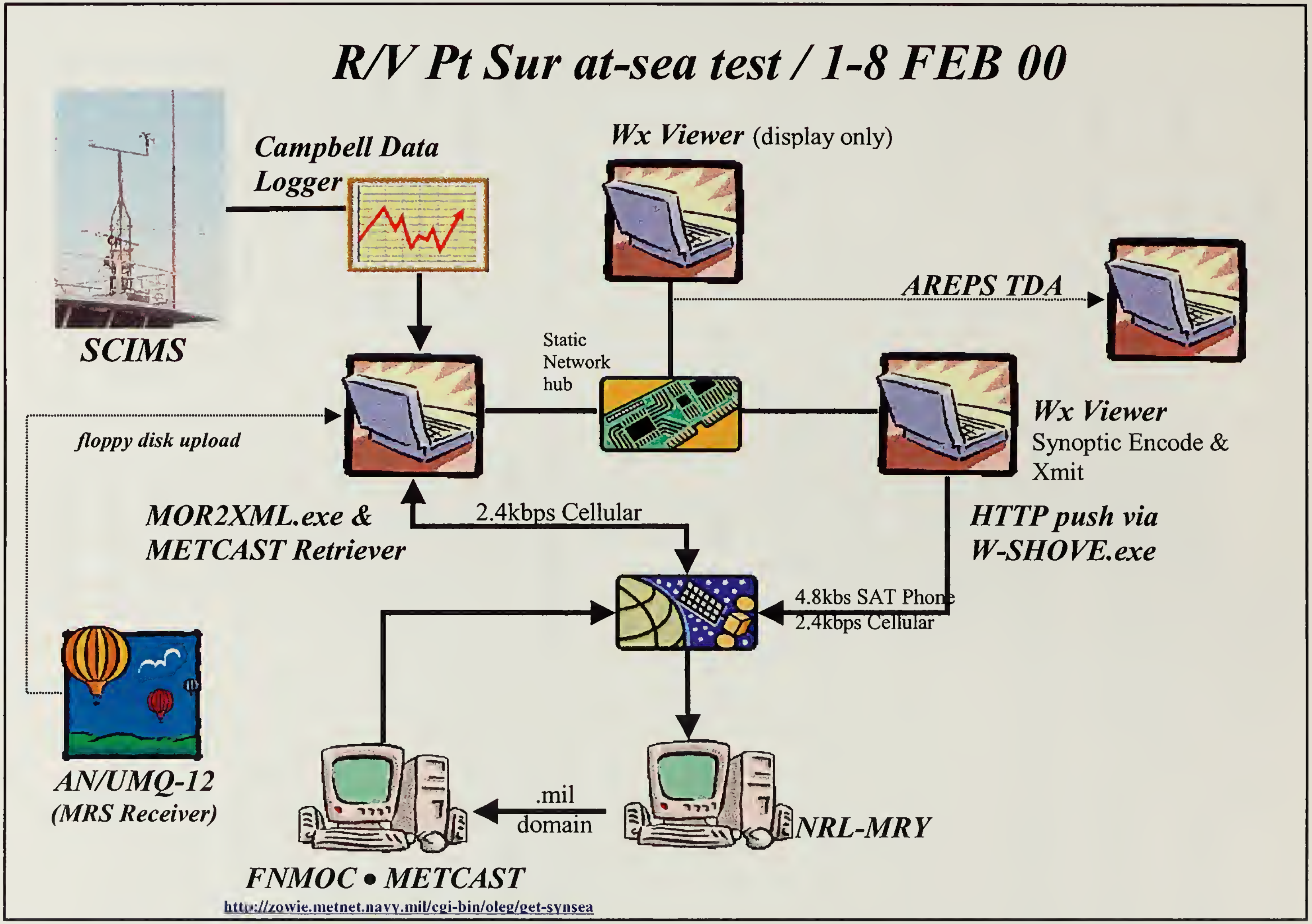

Figure 4-2 SCIMS / WxViewer Client network configuration on board R/V Pt. Sur 1-8 Feb00.

Component	Manufacturer / model
Laptop computer	Toshiba 490XCDT laptop computer (366Mhz CPU, 160mb RAM, Win NT 4.0 w/ SP 6)
Laptop computer	IBM Thinkpad laptop (Pentium CPU, 40mb RAM, Win 95)
Laptop computer	Toshiba Tecra 700 laptop computer (120Mhz CPU, 128mb RAM, Win 95)
Network hub	HubSTACK 10Base-T
Zip drive	Zip (parallel port)
Laser printer	HP-5 Laser Jet

Table 4-2 SCIMS / WxV Client network components.

C. EXTERNAL COMMUNICATIONS

A primary assumption of the demonstration relative to MORIAH initial operational capability was the availability of full-time fleet communications links with shore activities to transmit observation data more frequently than the current three or six hourly cycle. Dial up connections via NRL Monterey provided access to Internet based military domains (.mil). These were achieved via cellular and satellite based telephone communications systems. A standard PC modem served as the interface with the ships Motorola® cellular telephone. The COMM port on the Tectra 700 laptop computer was configured as a standard 9600 baud modem and connected to a KVH Tracphone® satellite telephone system via RS-232 cabling (Figure 4-3). Connection rates often reached 7.2kpbs and occasionally as high as 12.0kbps. Both phone systems were observed to be extremely reliable. Current options for relaying measurement data ashore are limited to DMS transmission of manually encoded synoptic observations.

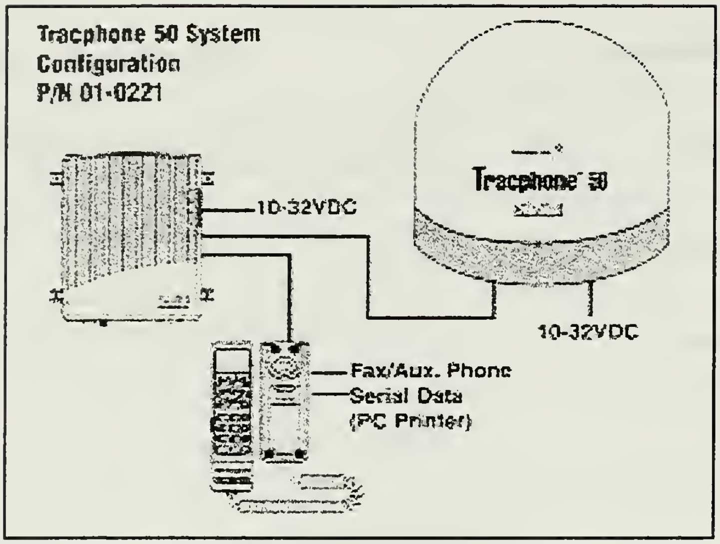

Figure 4-3 Satellite telephone system similar to the system installed in R/V Pt. Sur (from M.J. Sales, Inc., 2000).

D. AN/UMQ-12 MINI-RAWINSONDE SYSTEM

A standard fleet issue radiosonde system (AN/UMQ-12 system, Figure 4-4) was installed on the Pt. Sur and provided upper air data in support of numerous projects. Although the UMQ-12 was not interfaced directly with the SCIMS network, a separate PC was used to ingest pre and post processed data from the UMQ-12. UMQ-12 post-processing includes output of WMO coded reports that were subsequently transferred to WxViewer via floppy disk. Once the coded report data was uploaded to WxViewer, it was relayed to METCAST using the W-SHOVE.EXE software.

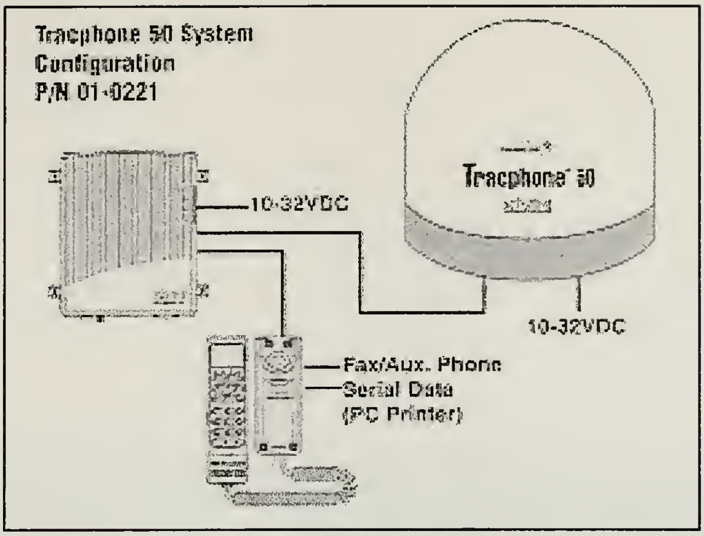

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Figure 4-4 A/N UMQ-12 Mini-rawinsonde system.

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V. SOFTWARE

A. DATA MANAGEMENT AND DISPLAY

A Campbell Scientific Inc.® (CSI) Data Logger System and associated software controlled all input/output (I/O) functions between the data logger and it's serial interface with the host CPU; acquisition and processing of all sensor and GPS data stored by the logger; and execution of associated Visual Basic programs.

PMW-185 and SSC Charleston developed WxV Client. It is designed to emulate client-side display and data management of current METOC observation data and includes procedures for encoding required reports for transmission ashore based on available communication paths. The MORIAH / WxV Client system configuration includes a MS Windows® (WIN) NT server functioning as a data processor and interface between WxV Client and the MORIAH data logger built by JHU-APL. The system used here did not include the NT server and therefore, it was necessary to modify the client software in order to manage and display measurement data collected by the CSI Logger. The WxV software was modified to operate with the logger, while retaining the functionality of WxV Client required to process synoptic observations and generate remote displays. These modifications limited the functionality of the client to text and graphical displays of one and five minute averaged measurements, and encoding of synoptic observation reports. Time series displays were also not available.

Microsoft® Visual Basic 6.0 was used exclusively to develop source code for executable programs designed to control data formatting, distribution, and archival functions of one-minute and five-minute data acquired by the CSI Logger.

B. SHIP TO SHORE DATA RELAY

W-SHOVE.EXE was developed by FNMOC. This is an executable program used to "push" formatted reports from WxViewer to a METCAST server using standard Internet protocols. For this demonstration, Internet connectivity was established with FNMOC

via dial-up connection to NRL Monterey. For real-time fleet (USN) operations, secure Internet (SIPRNET) connectivity could be achieved via existing fleet communications.

METCAST 1.2 was developed by FNMOC and is a Internet based application software designed to automate retrieval of real-time observation data, modeled forecast fields, satellite imagery, warning information, etc. As described in the User's Manual for the METCAST Client Segment (Release 1.2),

> METCAST is a standards-based, request-reply and subscription (channel) system for distributing weather information over the Internet using Hyper-Text Transfer Protocol (HTTP) and Multipurpose Internet Mail Extension (MIME). The METCAST Client Segment includes a graphical user interface (GUI) to allow the user to select the products to be retrieved and the frequency and types of retrievals, and a retriever process that establishes communications with a METCAST server, submits a request for the data requested, and delivers the reply to the local user.

The METCAST server stores current observation data and numerical model output fields. Fleet users remotely connect to the METCAST server to "pull" updates to requested data at a frequency set by the user, in the METCAST retriever set-up.

C. APPLICATIONS

1. Advanced Refractive Effects Prediction Systems (AREPS) 1.1

Developed and distributed by SPAWARSYSCOM San Diego (Code D883), AREPS is a tactical decision aid for computing and displaying electro-magnetic / electro-optic sensor performance including: radar probability of detection, Electronic Support Measure (ESM) vulnerability, UHF-VHF communications, and simultaneous radar detection and ESM vulnerability (SPAWAR D883 (1998)). All performance predictions are displayed as a function of height, range, and bearing. METOC data input includes various forms of temperature, humidity and pressure versus height profiles in order to compute vertical profiles of refractivity. AREPS also includes terrain features and range dependent processing and is capable of ingesting atmospheric and refractivity profiles from real-time remote sources including METCAST and TEDS as well as climatology data.

2. Joint METOC Viewer (JMV) 3.2

Developed by FNMOC, JMV is used in conjunction with METCAST to display retrieved observation data, imagery, and numerical forecast fields. JMV also provides a number of user editing tools for annotating screen displays, as well as functions for displaying aircraft and ship routes, tropical storm warnings, etc.

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VI. DATA COLLECTION AND DISPLAY

A. METOC DATA

The CSI was programmed to capture raw measurement data every 15 seconds, using the sensors listed in Table 4-1. During the first phase, data was collected from all sensors except for the GPS receiver. Except during the system outages shown in Figure 6-1, both one minute and five-minute averaged data were archived every 60 seconds. Table 6-1 lists each element of the archive files. Hardware and/or software conflicts appear to have caused the CRX-10 data logger to not process GPS data. However, data from the starboard tower GPS unit was interpolated onto the SCIMS data set in order to geo-locate data collected during this phase of testing (Figure 6-2). Figures 6-3 through 6-6 show time series of primary data collected via sensors located on the port-side SCIMS tower.

Date-time group	Infra-red sea surface temperature
Latitude	Relative wind direction
Longitude	Relative wind speed
GPS course	True wind direction*
GPS speed	True wind speed*
Air temperature	Air pressure
Dew point temperature*	Relative humidity

* = derived values

Table 6.1 Navigation and METOC elements collected via CSI data logger.

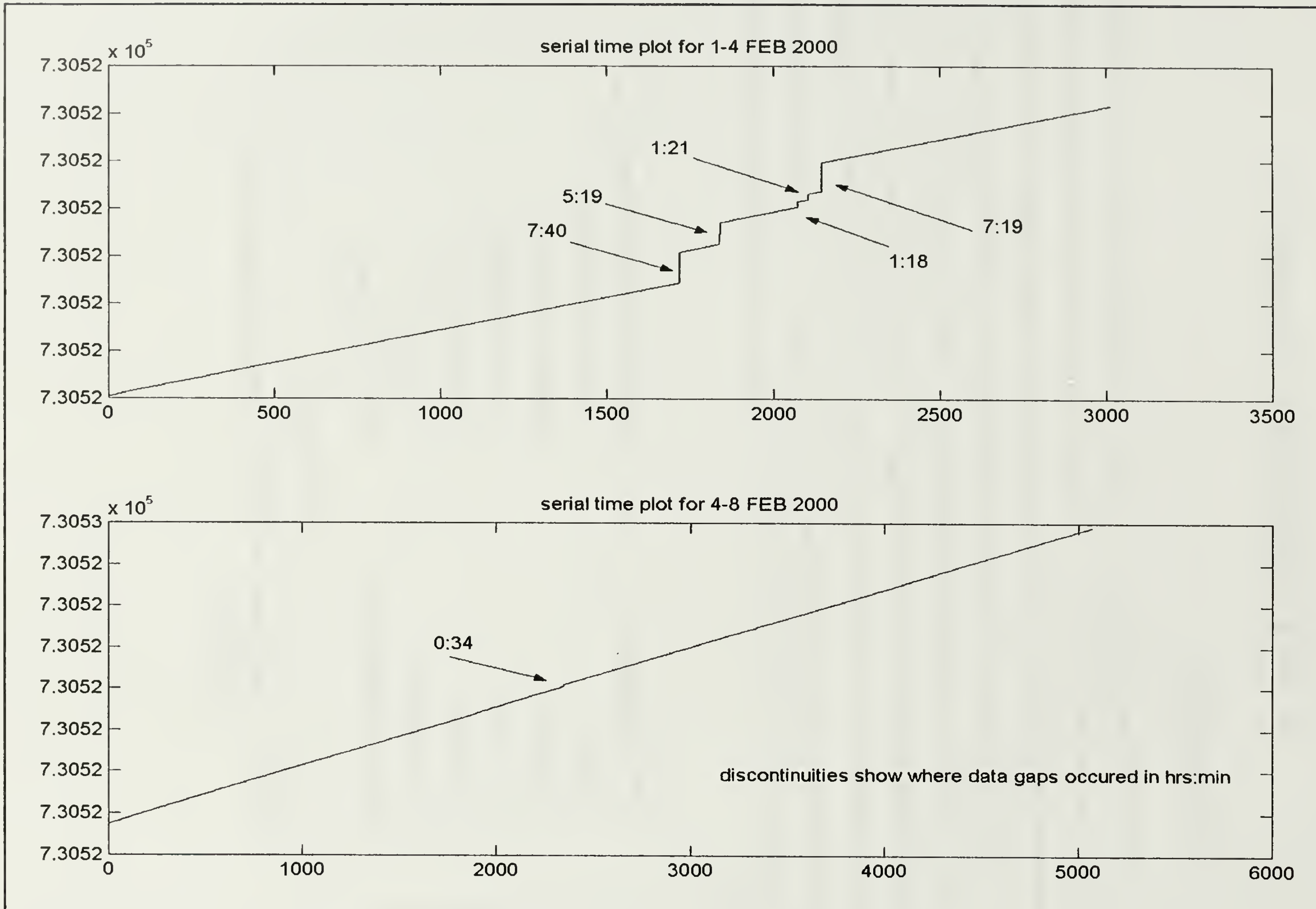


Figure 6-1 Serial time plots indicating when SCIMS data collection failed.

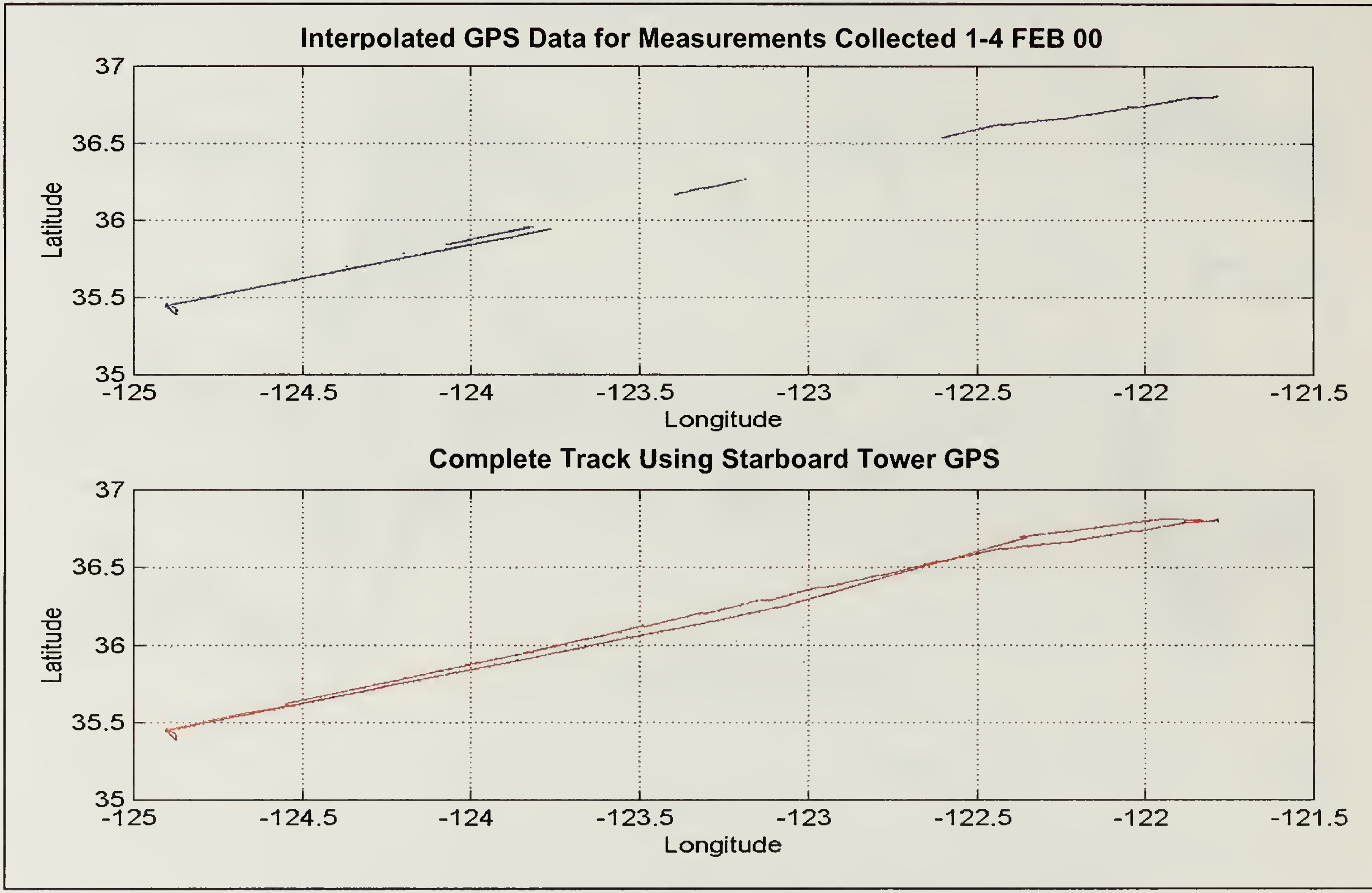


Figure 6-2 Interpolated and complete GPS tracks for 1-4 FEB 00

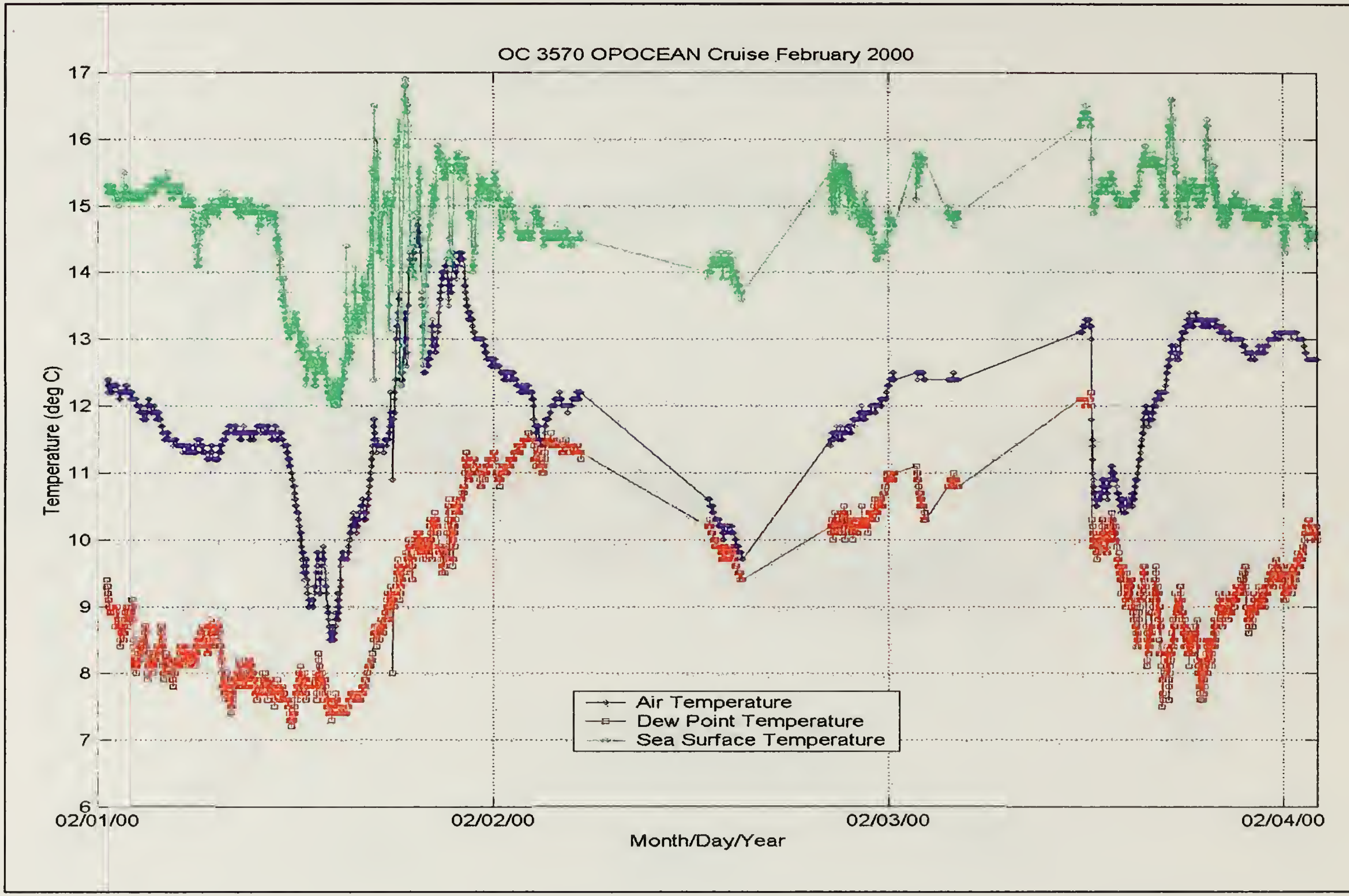


Figure 6-3 SCIMS temperature data collected on R/V Pt. Sur 1-4 FEB 00

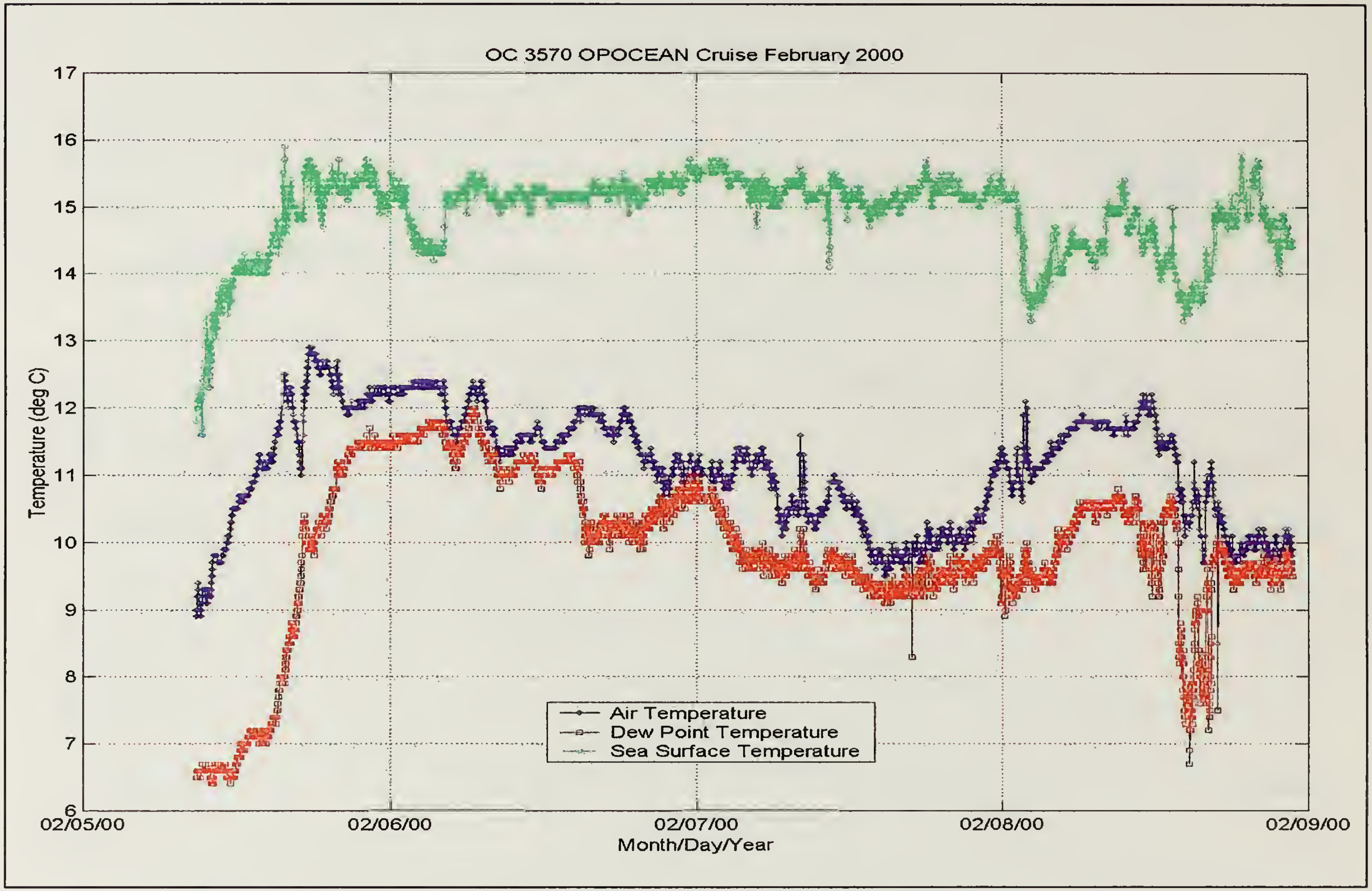


Figure 6-4 SCIMS temperature data collected on R/V Pt. Sur 5-8 FEB 00

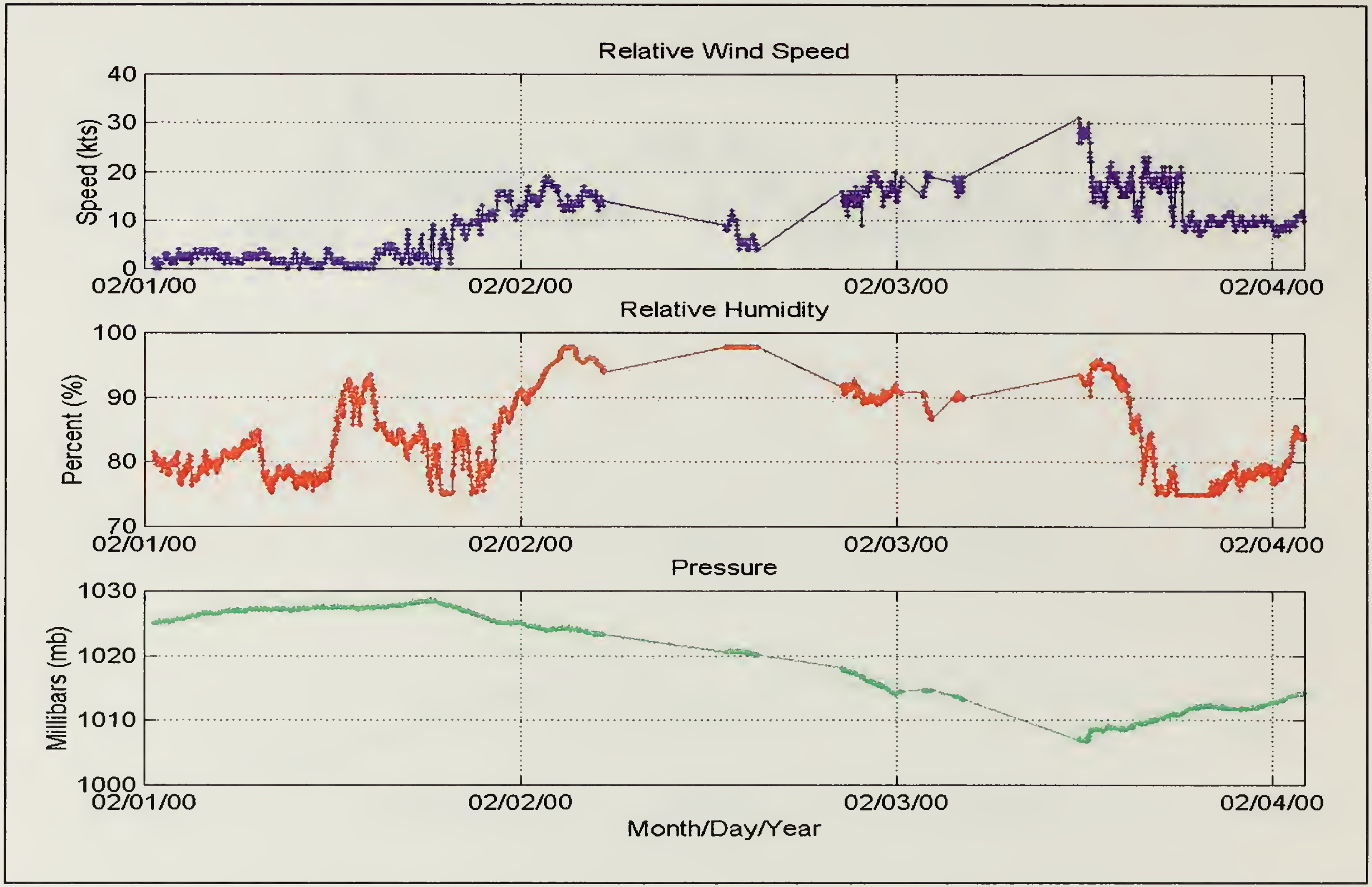


Figure 6-5 SCIMS data collected on R/V Pt. Sur 1-4 FEB 00

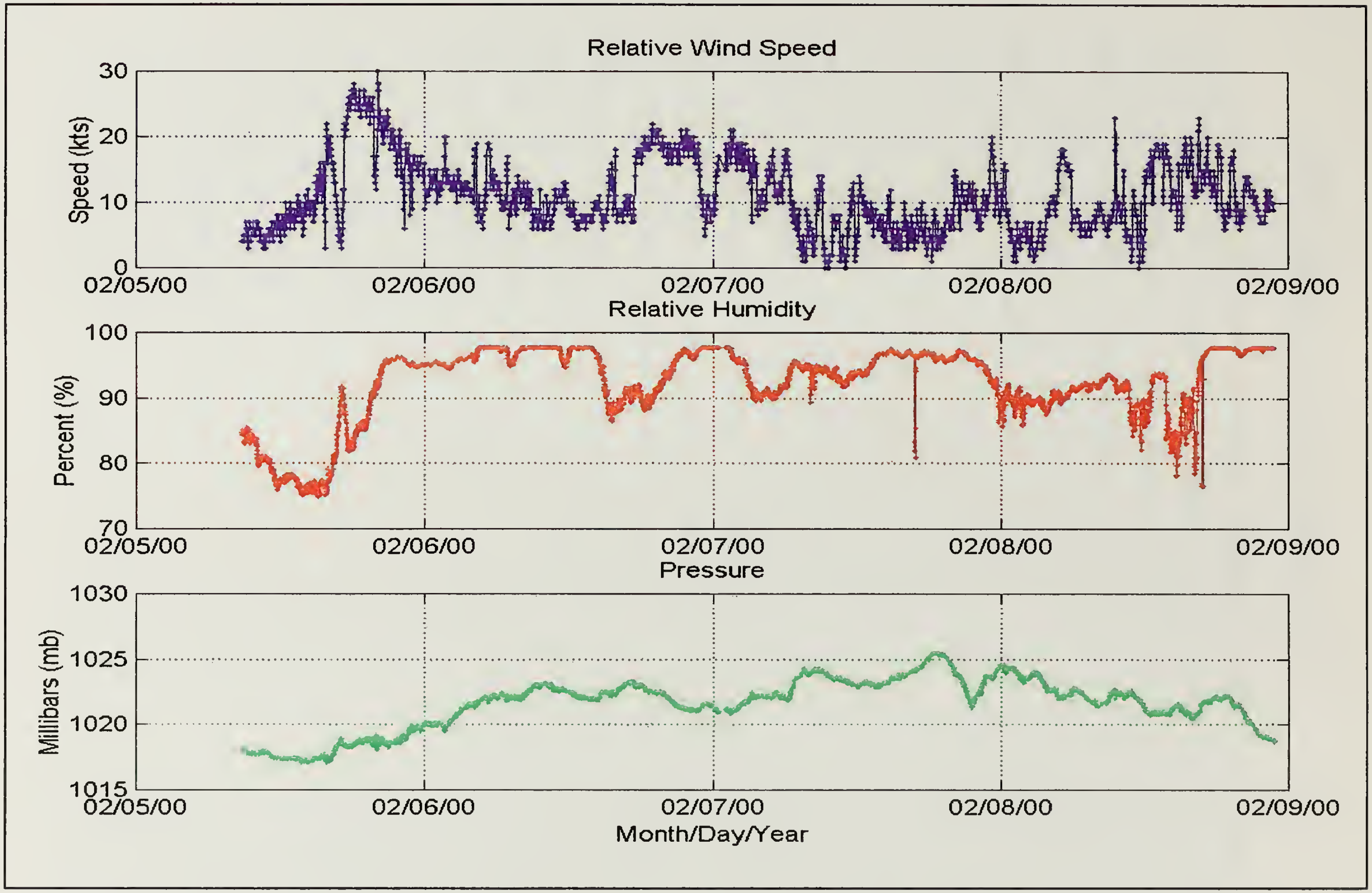


Figure 6-6   SCIMS data collected on R/V Pt. Sur 5-8 FEB 00

B. LOCAL AND REMOTE DATA DISPLAYS

In terms of its original design and capability, PMW-185 implemented significant modifications in the WxV Client software however; the modifications did provide for full time continuous displays in various formats. Figure 6-7 shows the local display of primary and derived METOC parameters. Original design of WxV Client provided for a 2 second (0.5Hz) refresh rate for displaying wind direction and speed data that visually appears continuous on dial type displays (Figure 6-7). In consideration of hardware and software constraints, the CSI data logger was set up to download raw measurements every 15 seconds and averaged measurements every 60 seconds. As a result, the update cycle for the wind dials was every 60 seconds. The modifications that were necessary to make WxV Client run with the CSI data logger vice the WIN NT server as originally designed, also caused the missing data indicated in Figure 6-7. Nevertheless, supported data fields automatically updated every 5 minutes along with position data. Due to an error in the applicable algorithm, true winds were in error for the entire test.

The availability of shared data files on the WxV network supported the remote displays shown in Figure 6-8. These displays are primarily based on existing SMOOS screen designs (SPAWAR D642). This particular functionality demonstrates that the operation of WxV Client software on a network, supports remote display of continuously updated weather information (at any node on the network).

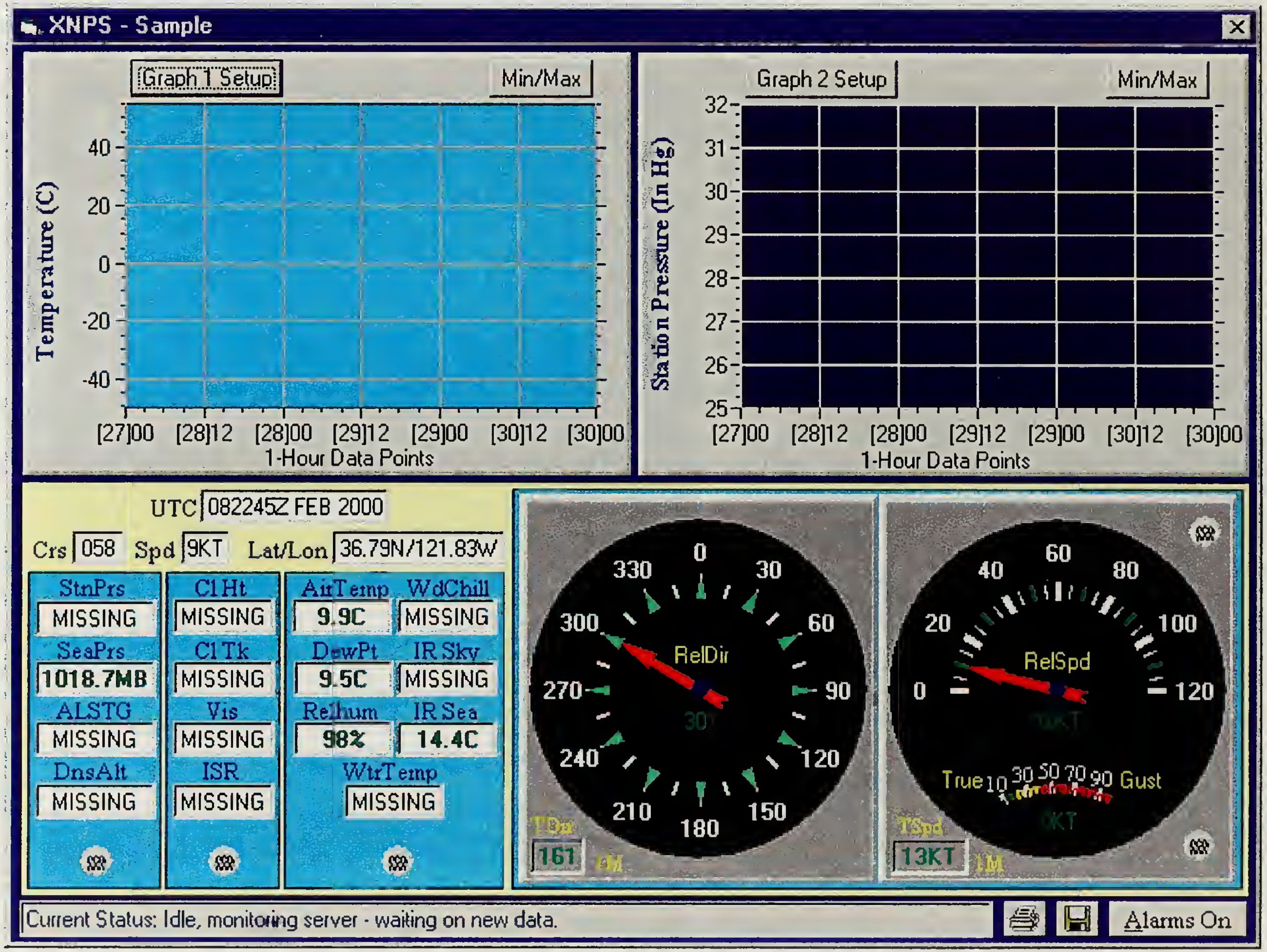
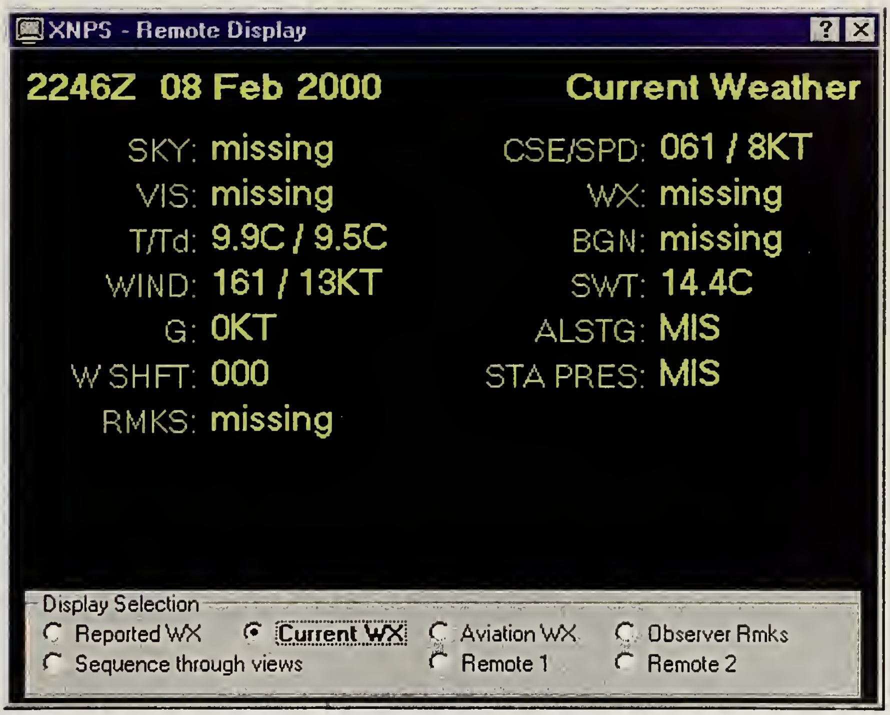


Figure 6-7 WxViewer Client current data display.



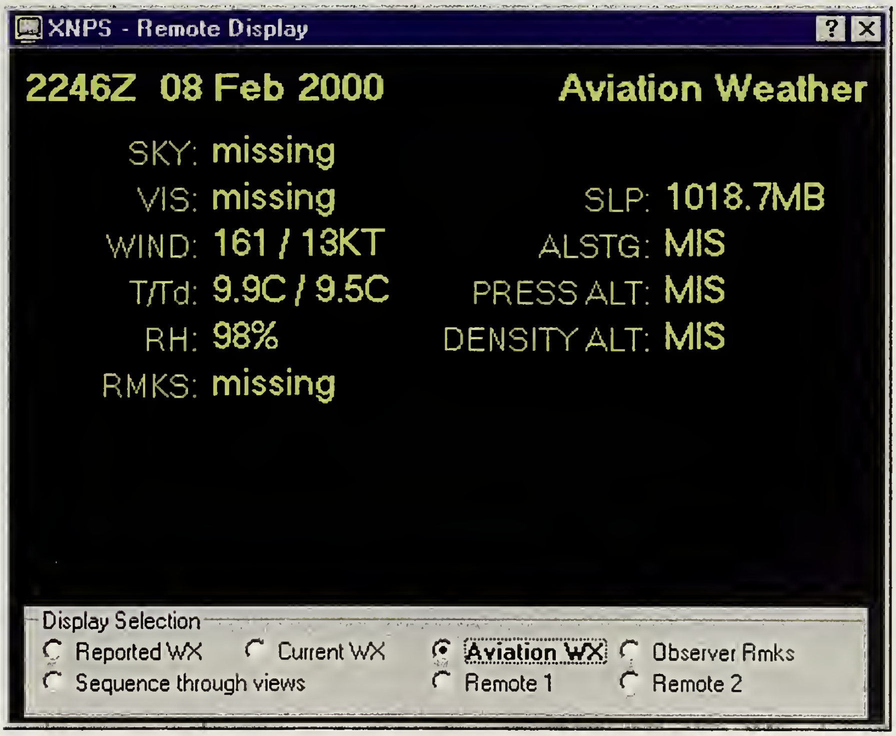


Figure 6-8 WxViewer Client remote displays – Current Weather (above) and Aviation Weather (below).

VII. ENCODING AND TRANSMISSION OF METOC OBSERVATIONS

A. CURRENT REQUIREMENTS

Present requirements for encoding and transmitting METOC observations are established by Naval METOC Command Instruction (NAVMETOCOMINST) 3140.1K. It requires all surface combatants to record observation data hourly, and transmit ship synoptic observations every three or six hours depending on the wind and/or sea conditions experienced at the time of the observation. Twice daily upper air observations are normally executed only by those units with an OA division (Aerographer's Mates permanently assigned as ship's company), an embarked Mobile Environmental Team, or by deployed USMC units. Table V-2 of NAVMETOCOMINST 3140.1K also prescribes the precedence at which observations are transmitted by record message systems. Ships experiencing 35kt winds and/or 12ft or greater seas are required to send their observations every three hours, via immediate precedence. Otherwise, observations are sent every six hours as priority message traffic.

B. SEMI-AUTOMATED OBSERVATION ENCODING VIA WXV CLIENT

WxV Client supports logging of hourly weather observations, and semi-automated encoding of surface synoptic and upper air observations. Figure 7-1 shows the synoptic observation input screen. Depending on the sensor configuration and/or derived values (i.e. dew point temperature, true winds, etc.) that are available, WxV Client automatically populates observation element input cells (i.e. air and sea surface temperatures, atmospheric pressure, winds, etc.). Manual entries such as present weather, cloud types, and wave information are required for those elements not measured by MORIAH or other automated sensors. As each cell is populated, the synoptic report is automatically formatted in accordance with NAVMETOCCOMINST 3144.1D. The completed report is saved as a generic text file and is then available for transmission to

shore sites using W-SHOVE.EXE. The version of WxV Client used for this project was limited to preparation of synoptic observations only.

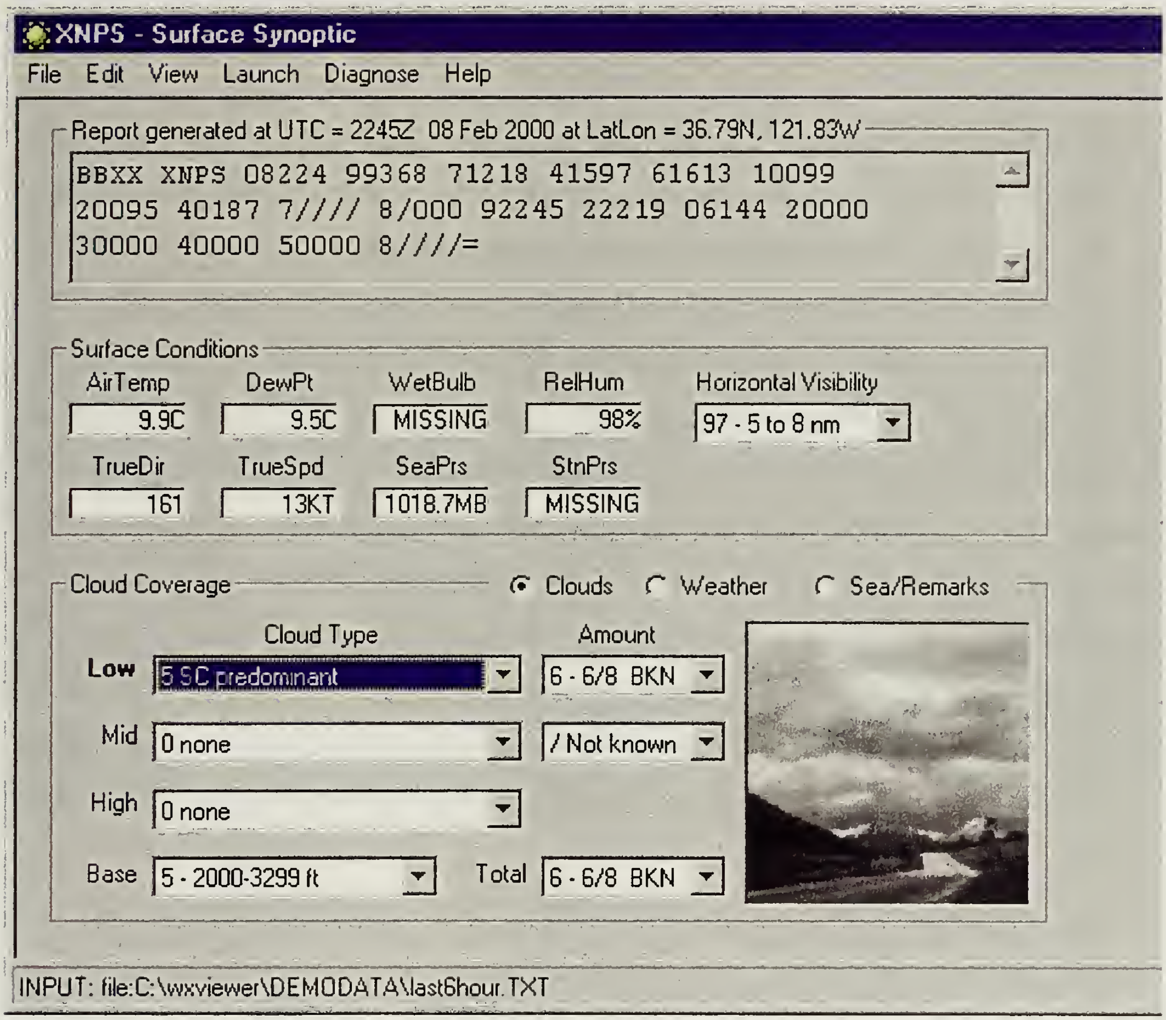


Figure 7-1 WxViewer Client Surface Synoptic Observation input screen.

C. AUTOMATED TRANSMISSION TO SHORE-BASED METCAST SERVERS

During the R/V Pt. Sur testing, approximately 32 surface and six upper air observations were prepared and sent to the METCAST server at FNMOC using W-SHOVE.EXE. All surface synoptic observations were encoded as described previously.

Since the AN/UMQ-12 automatically generated the coded reports, text files containing the upper air reports were uploaded to the WxV Client laptop via floppy disk. Given the assumption that normal fleet operations would permit (near) continuous transmit capability, observations were encoded and transmitted without regard to any particular schedule. Internet connections to the METCAST server were established by dial-up connection to NRL Monterey using both the KVH Tracphone® and cellular phone systems. Depending on the type of report, surface or upper air, the W-SHOVE.INI was modified (via .bat file) to identify the correct channel at the METCAST server site.

The transmission of surface observations was periodically verified by web-browser based data retrievals from the METCAST server. Verification was similarly conducted at NRL and NPS. The successful transmission of data to and from the ship demonstrated the ability to use standard HTTP Internet protocols and telephone links. Fully automated processing of surface observations is limited by the requirements, specified in NAVMETOCCOMINST 3144.1D, for manual entries of cloud layers, cloud type, visibility and present weather, and sea/swell wave data. Given the successful relay of semi-automated data to METCAST servers ashore, observations not requiring manual entries could be encoded and relayed without any human intervention at the maximum frequency sustainable by the communication path in effect.

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VIII. RETRIEVAL OF REAL-TIME DATA VIA METCAST/ JMV

A. METOC ANALYSIS AND FORECASTING

The primary objective in retrieving WMO coded data while underway was to (1) demonstrate the value of integrating locally acquired measurements with other forms of real-time observed data (i.e. buoy reports, satellite imagery, etc.) and numerical weather prediction products (NWP) and (2), use retrieved data in TDAs.

METCAST software allows users to set up tailored product requests based on geographic boundaries and/or numerical model output. Figure 8-1 is a sample showing how multiple sources of data are combined and displayed as a single integrated product. This particular example includes real-time observation data from coastal buoys and ship reports available within the geographic area of the background chart. The ship report identified by the XNPS call sign and decoded in Figure 8-2 signifies the successful transmission of Pt. Sur data to the shore based METCAST server site. This example also includes three NWP products from FNMOC namely, a sea height analysis, surface wind direction and speed analysis, and surface pressure analysis. A forecasters ability to predict tactically relevant weather parameters is directly related to his or her ability to synthesize current and/or forecast conditions. A battlegroup with multiple MORIAH systems will ultimately provide on-scene forecasters with highly accurate, more frequent, and spatially distributed observations with which they can better evaluate higher resolution METOC models. Future mesoscale model (i.e. NOWCAST) output may consist of hourly forecasts of winds and seas over a particular operations area (OPAREA). Hourly observation data provided by MORIAH systems within a battlegroup will provide the forecaster with the only tool available to readily evaluate, adjust, and verify the accuracy of the NOWCAST output, and make adjustments to the forecast accordingly.

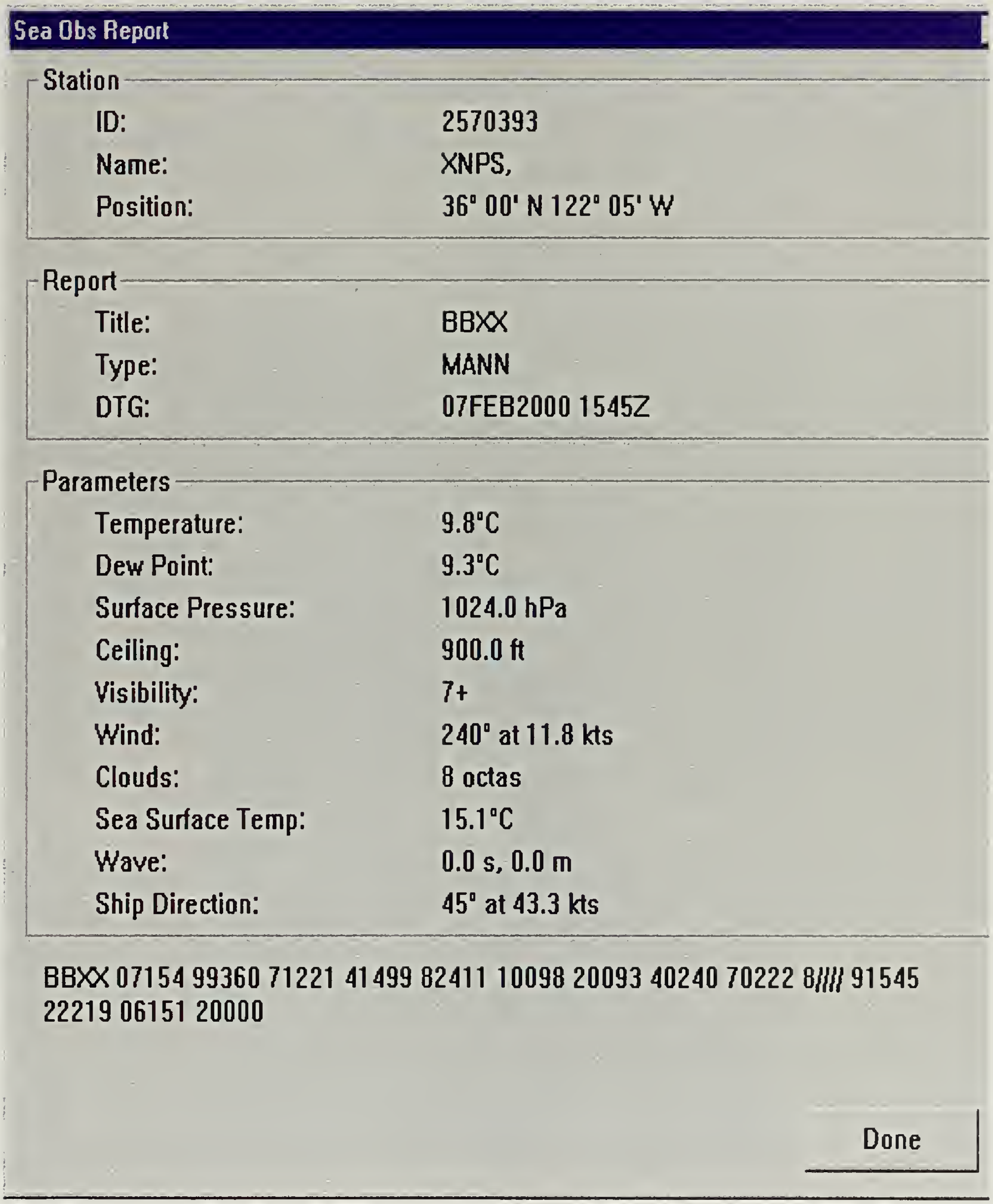

Figure 8-1 In-situ ship synoptic observation report from R/V Pt. Sur retrieved from METCAST.

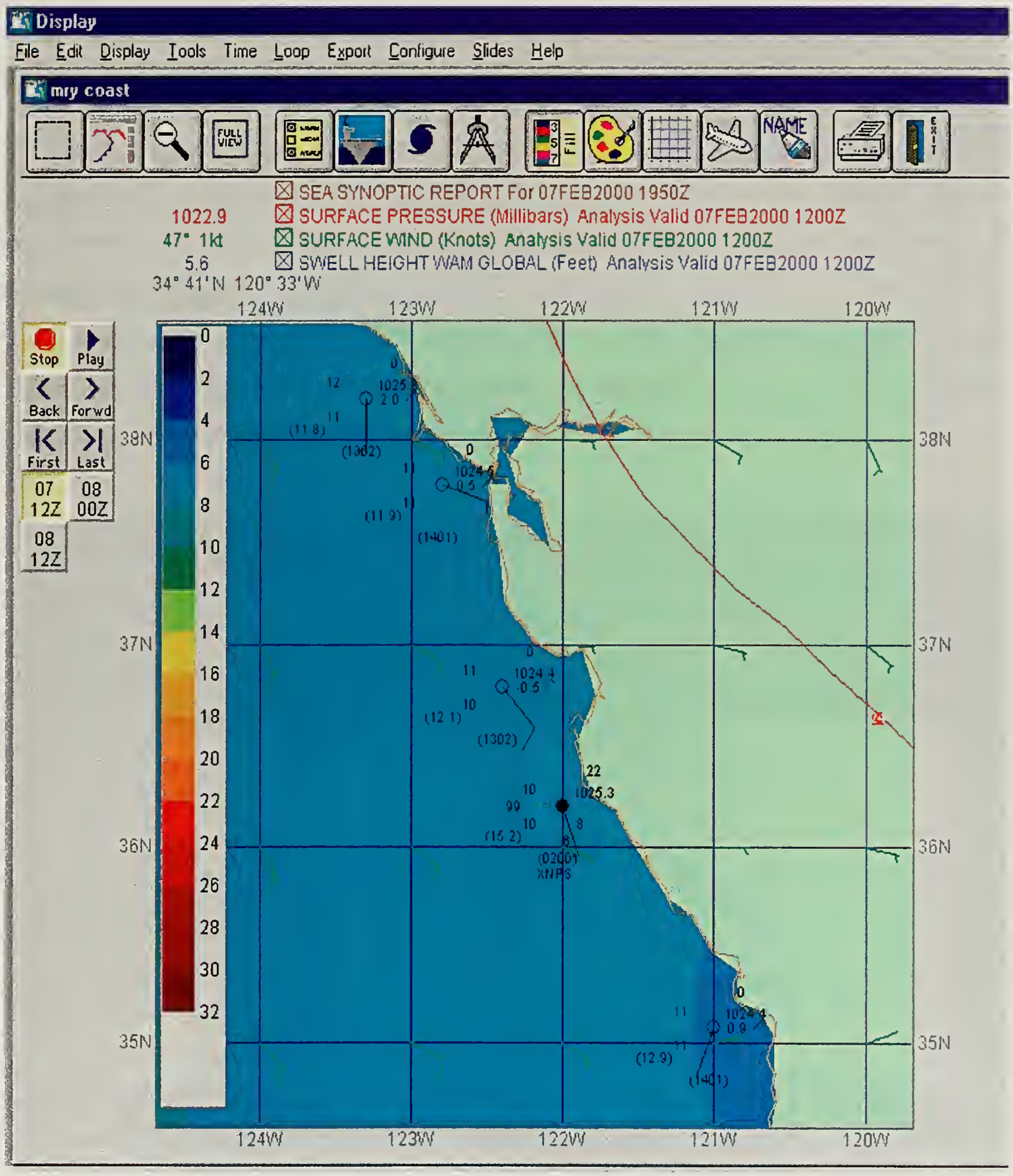

Figure 8-2 Real-time synoptic ship and buoy reports displayed with current analysis fields retrieved via METCAST.

B. TACTICAL APPLICATION OF DEMONSTRATED CAPABILITY

1. Use of Retrieved Data in TDA's

In addition to surface observations, METCAST servers also store available upper air soundings from shore sites and AREPS is configured to locate upper air data retrieved by METCAST (for display by JMV). Figure 8-3 shows available shore-based soundings, retrieved via METCAST, that are available for selection by AREPS for evaluating EM system performance. Retrieval of shore based upper air data via METCAST and subsequent ingest into AREPS TDA software demonstrated the potential capability to use other than own ship sea-based upper air reports for on-scene TDAs once parsers for sea-based upper air reports are implemented in METCAST servers.

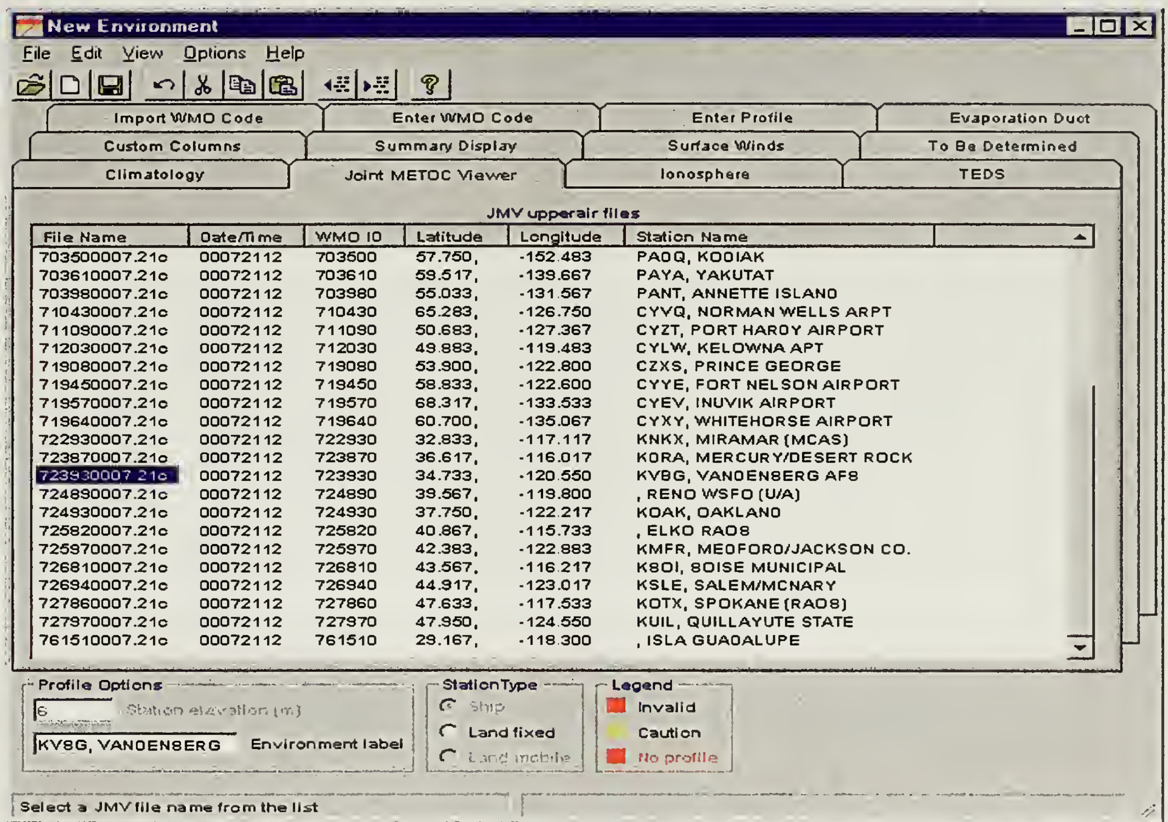

Figure 8-3 AREPS 1.1 New Environment – Joint METOC Viewer data selection screen.

2. Use of Acquired Data in TDA's

Atmospheric temperature and humidity profiles in the near surface region just above the ocean surface are key parameters in the calculation of electromagnetic (EM) wave propagation and related sensor performance algorithms within the marine boundary layer. Evaporative duct height (EDH) is used to characterize the depth of the boundary layer and is a derived from bulk surface flux measurements (Figures 8-4 and 8-5). As a function of frequency, EDH values determine what type (sub, normal, super, or trapping) of EM refraction will occur and therefore affect EM and optical sensors within and/or slightly above the marine boundary layer. The tactical significance of EDH variation in space and time was described in paragraph III.B. above. To reiterate, variability in observed sensor measurements results in similar variations in TDA derived sensor performance estimates. Figures 8-6 and 8-7 show the air-sea temperature difference and corresponding variability in calculated evaporative duct height (z*). Both temporal and spatial variations, regardless of location, demonstrate the need for continuous measurements and concurrent updates to weapon and sensor performance predictions.

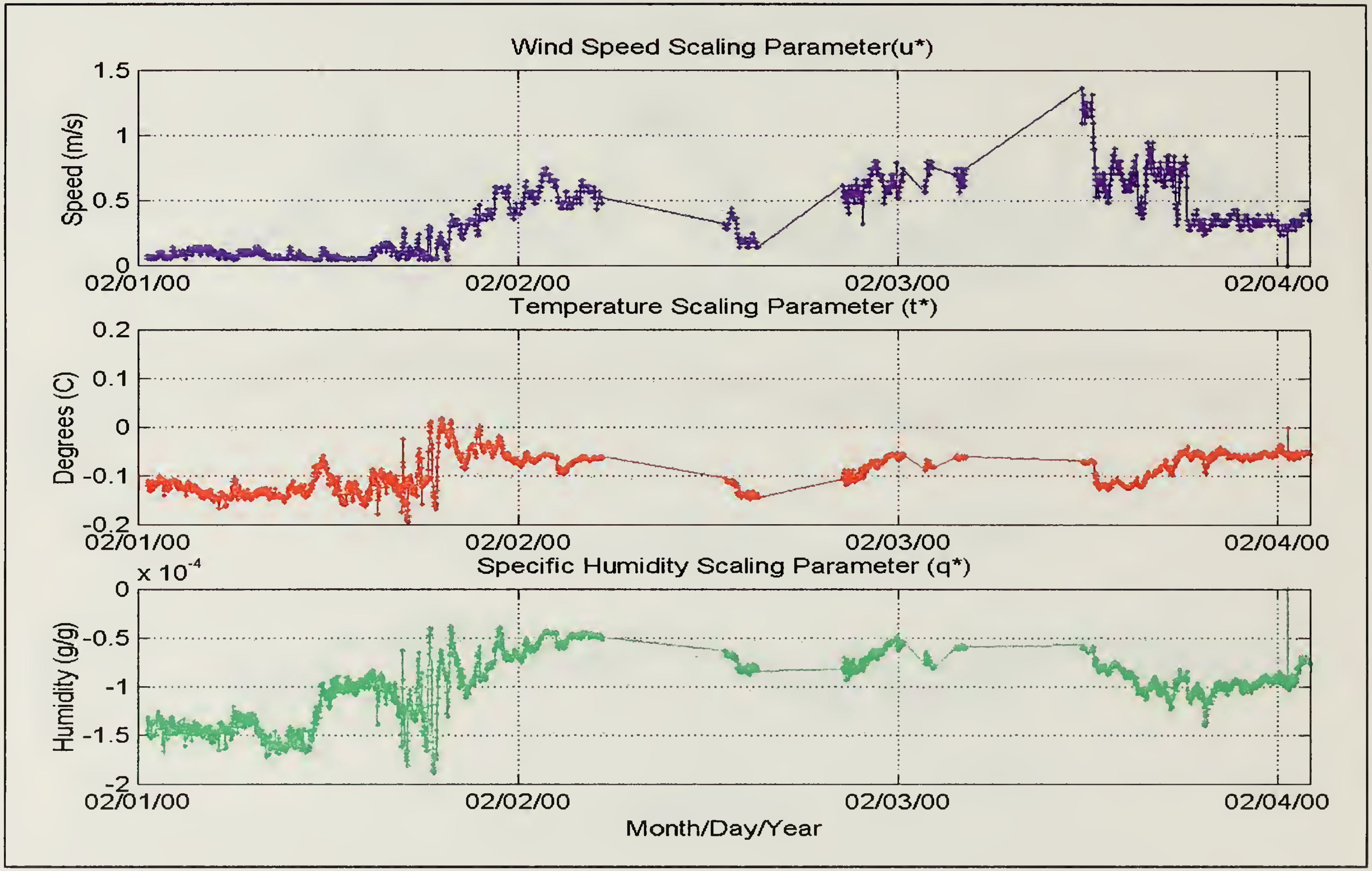

Figure 8-4 Scaling parameters based on measurements for 1-4 FEB 00

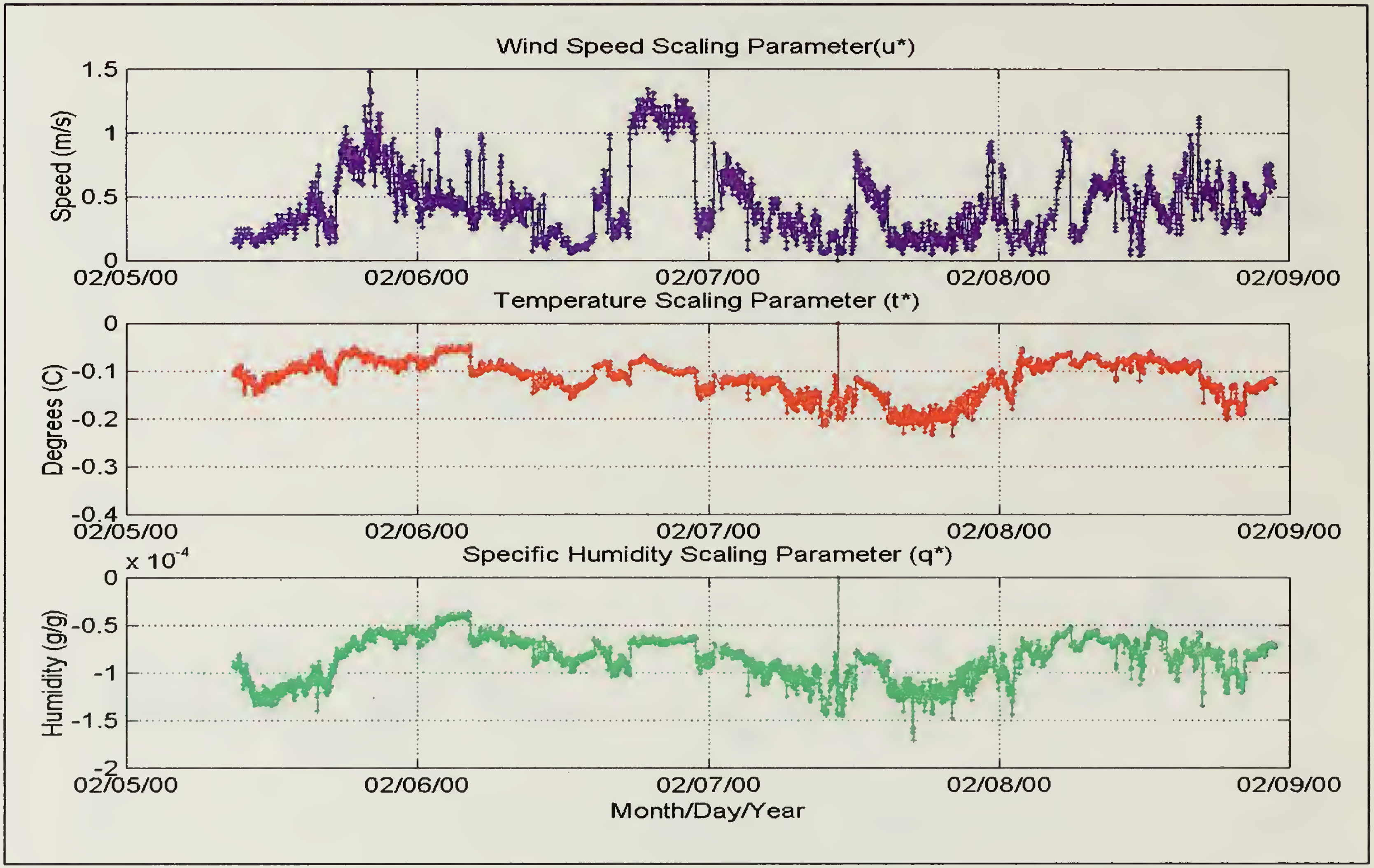

Figure 8-5 Scaling parameters based on measurements for 5-8 FEB 00

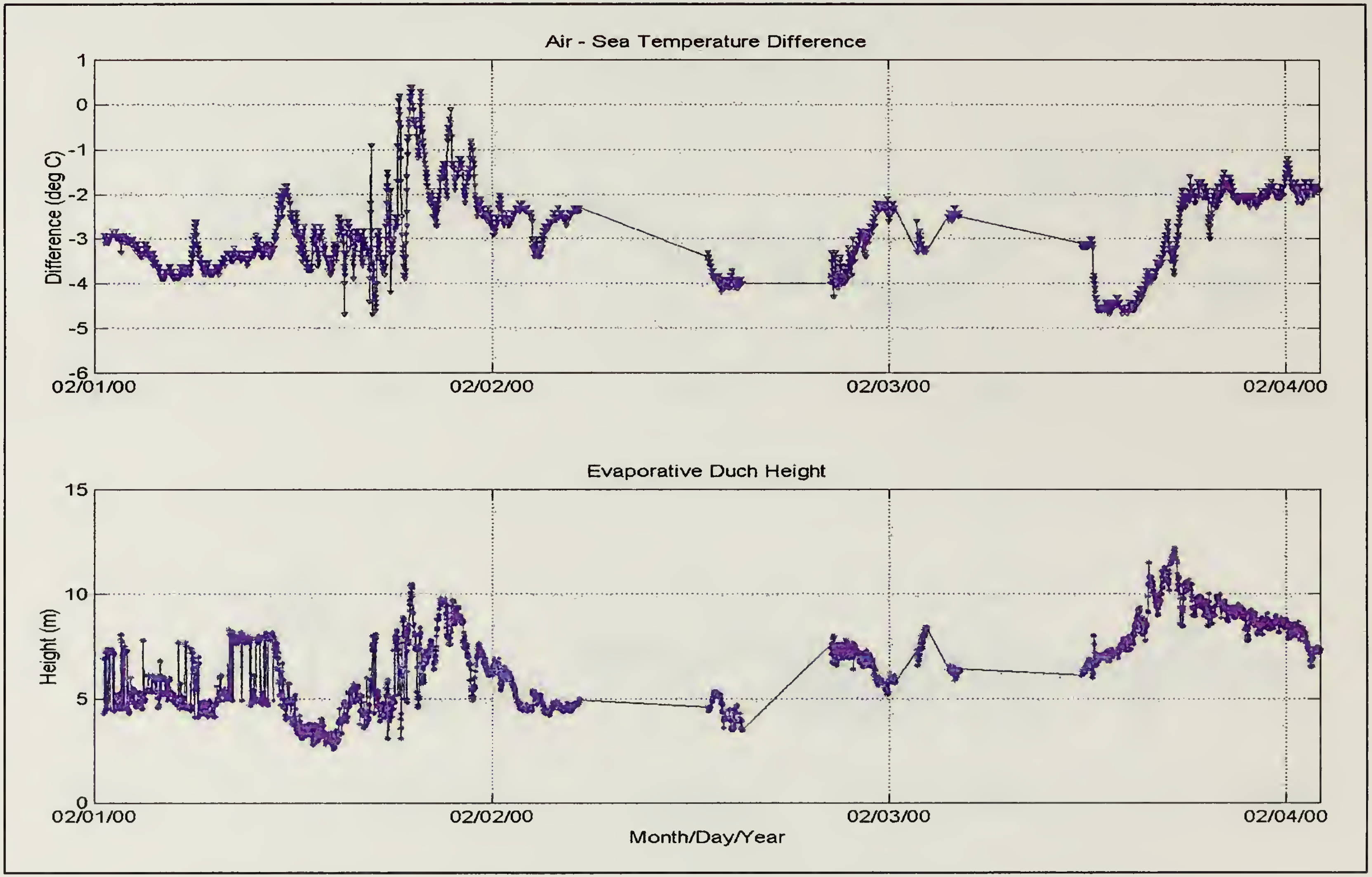

Figure 8-6 Air-sea temperature difference and evaporative duct height for 1-4 FEB 00.

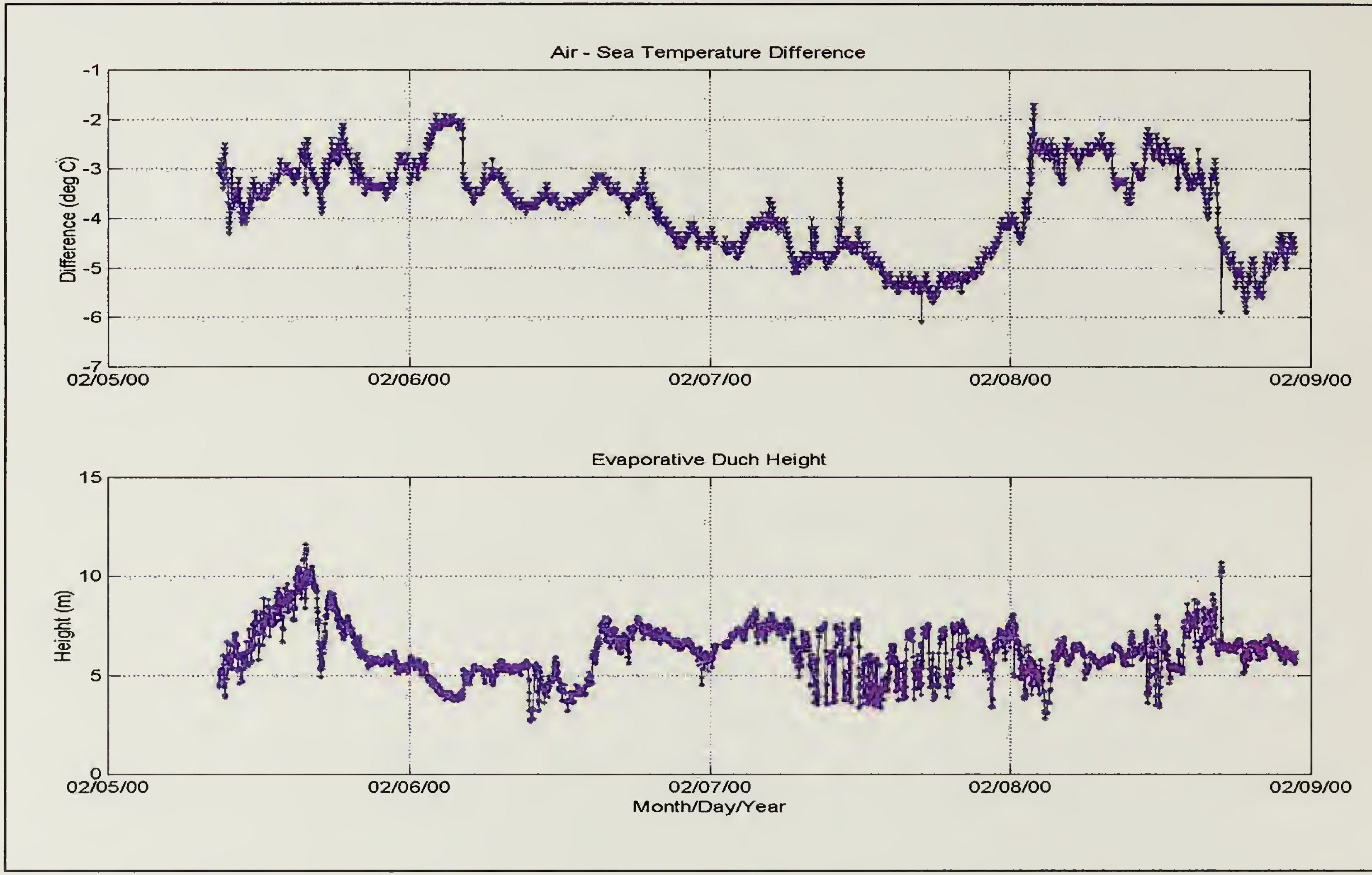

Figure 8-7 Air-sea temperature difference and evaporative duct height for 5-8 FEB 00.

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IX. CONCLUSIONS AND RECOMMENDATIONS

Conclusions from this study relate to four distinct operational activities; 1) METOC data collection and display, 2) Encoding and transmission of WMO coded reports, 3) Acquisition of WMO coded data and other numerical weather products while underway via METCAST, and 4) Use of WMO coded upper air reports retrieved via METCAST in tactical decision aids. Further, since these are current operational activities, there are issues that the conclusions address, immediately. Therefore, accompanying the conclusions are statements of the issues and conclusion based recommendations

A. METOC DATA COLLECTION AND DISPLAY

Automated METOC data collection was accomplished using the CSI data logger and demonstrated the effective use of COTS hardware and software to acquire data continuously. The application of visual basic programs used to format and store acquired data in various formats illustrates the flexibility to use such data in numerous applications including meteorological analysis and forecasting, extending climatological archives, and visual displays for a variety of user needs.

Issue: Automated measurements for small craft.

The SMOOS(R) and MORIAH systems currently under development are programmed for installation aboard USN surface combatants and deep draft vessels operated by the Military Sealift Command only.

Recommendation:

- NAVSEASYSCOM develop a SCIMS / WxViewer type package for harbor craft and other surface units conducting non-tactical operations i.e., fleet tugs, floating drydocks, etc.

B. ENCODING AND TRANSMISSION OF WMO CODED REPORTS

WxV Client was used to prepare WMO coded synoptic weather reports using formatted input data from SCIMS. The AN/UMQ-12 prepared WMO coded upper air reports at the conclusion of each sounding. With W-SHOVE.EXE integrated as a menu selectable function in WxV, transmitting reports directly to the METCAST server at FNMOC was only dependant upon a satisfactory Internet connection ashore.

Issue: Policy regarding transmission of routine METOC reports.

The existing requirements for observing and reporting surface weather have not fundamentally changed in more than 25 years. Bridge watchstanders and OA division personnel continue to maintain a written record of current weather. However, observation data are rarely forwarded in a timely manner. In spite of the use of fleet wide computer based communication systems, observers are still required to manually record and process METOC reports. The result remains: long delays between the actual time of an observation and the time it is received at METOC production and regional fleet support centers. FNMOC statistics for the period 04-14 July 2000 (Table 9-1) show that a majority of WMO coded METOC reports received from USN units do not arrive in time for assimilation into initial model analysis runs. Unclassified USN reports arrive at FNMOC almost two hours later than unclassified non-USN reports, most likely due to internal routing and communications differences between military and civilian systems. These data samples further indicate that the majority of all unclassified USN reports arrive in excess of 2.5 hours after the actual observation time, or very close to the +3hr data cut-off time for inclusion; and many are too late for the data cut-off time. Confidential USN reports arrive an average of 3.1 hours after synoptic time, and thus, a majority does not make the data cut-off time. Contrary to the aforementioned, SECRET USN reports arrived on average, within 15 minutes after the observation time however, this represents less than 6% of all USN observations received during the 10-day sample (Carman, 2000).

There is a great benefit to be gained by streamlining the process of encoding the observation and transmitting it from the ship, both for unclassified and classified observations. Improving reporting timeliness would not only benefit Navy METOC modeling on both a regional and littoral scale, but would also make the observations available more quickly to operational units who need the data (Carman, 2000).

The existing requirement for afloat units to report synoptic observation every six hours is no longer sufficient in terms of the higher resolution data requirements or for maintaining a more effective weather watch. In preparation for the deployment of automated data collection systems aboard all naval combatants and USNS units, existing policy needs to be revised to reflect current as well as anticipated requirements and capabilities.

Classification and source of report		**# of reports**	**Average time of arrival after time of observation**
Unclassified	USN	556	2.6 hrs
	Non-USN	46562	0.8 hrs
Confidential	USN	628	3.1 hrs
	Non-USN	260	2.5 hrs
Secret	USN	74	0.2 hrs
	Non-USN	1738	6.9 hrs

Table 9-1 Average time delay (hours) for receipt of shipboard observations at FNMOC for the period 4-14 July 2000 (from Carman, 2000).

Recommendations:

- All ships continue to record hourly observation data however, if reliable communications are available, ships should also be required to transmit hourly observations to include information in columns A through G of CNMOC 3141/3 (REV. 1-96). A recommended report format is provided as Appendix (A);

- All ships continue to record and transmit synoptic observations in accordance with existing guidelines, every three or six hours when availability of communications precludes hourly transmission of observation data;

- Eliminate designation of weather guard-ships underway.

Issue: METOC data archive requirements.

Current guidance requires the forwarding of METOC observation records (paper forms (CNMOC 3140/12)) each month via regular mail. The use of WxV software to encode and transmit METOC observations also includes, an inherent capability to digitally archive that same data along with relevant station information, thereby eliminating the need to manually record and store observations as paper records. Appendix B contains a partial listing of data representing a typical archive file that could be generated for any underway platform. Benefits include: (1) eliminating the costs associated with printing large paper forms, (2) a reduction in manpower required for records maintenance and conversion of paper records to digital files, (3) a significant reduction in the time and expense of transferring monthly records by digital[2] methods to FNMOD Asheville, and (4) Potential ability to fully automate quality control processes.

Recommendations:

- Eliminate the requirement for paper records;

- Develop archive data formats that take advantage of current technology;

- Minimize the forwarding of archive files to quarterly or semi-annually

- Implement archive file handling internal to WxV Server

- Develop and integrate a NIPRNET/SIPRNET based feature for relaying archive data quarterly to FNMOD Asheville

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[2] Digital storage requirement for 24 observations per day per month is approximately 744 kb.

Issue: Observation quality control requirements.

The current practice of manually performing quality control of written records is time consuming and does not provide for real-time correction of transmitted errors. With the exception of the format and order of manual entries in the Remarks column of the surface observation log sheet (col 14), digital tools such as WxV Client can eliminate most observation errors by integrating error checking at the input interface

Recommendation:

- Eliminate manual quality control of surface observations with the implementation of digital tools for logging and encoding surface observation data.

Issue: Secure Communications.

The critical factor in getting METOC data into distribution systems is not generating the data but transmitting it to sea and/or shore based collection sites in a timely manner. As discussed earlier, recent statistics indicate that a large portion of USN ship reports, regardless of classification, are not relayed to FNMOC in time to be ingested into current model runs.

Although execution of the Pt. Sur demonstration used commercial communications, real-time operations ashore and afloat require secure communications and the ability to adapt to whatever circuit and/or routing is available at any given moment in time. As illustrated by Connon (1999), the shipboard communications center provides the circuit path to the automated digital network system (ADNS), and ADNS provides dynamic routing to/from points both ashore and afloat (Figure 9-1). Therefore, integrating WxV Client with the various shipboard communications (GENSER LAN, JMCIS, etc) paths will allow for maximizing the automation necessary to relay METOC data in a timely manner.

HTTP "push" technology was both effective and reliable during the Pt. Sur test. Modifications to WxV Client included the ability to execute W-SHOVE.EXE as an ordinary menu selection (Figure 9-2) and as a result, METOC observations (surface and upper air)

were transferred as plain language text (.txt) files from the laptop computer on Pt. Sur, directly to the METCAST server at FNMOC. This data transfer method required minimal bandwidth as synoptic and upper air report files were less than 1kb in size. The use of W-SHOVE.EXE or similar type of HTTP based relay should be exploited to the maximum extent; in order to take advantage of ADNS based sea-to-shore connectivity. It is noted that W-SHOVE.EXE failed in a real-time operating environment due to non-standard configurations at the Pacific network operations center (NOC) firewall (Connon (1999)). However, Huff and Kiselyov (2000) recently confirmed that implementation of HTTP 1.1 protocols at fleet NOCs, will ensure reliable data transfers using W-SHOVE.EXE.

As illustrated in Figure 9-1, Navy ships outfitted with ADNS equipment are capable of relaying message traffic on demand. This capability allows for the use of standard HTTP and e-mail protocols for transmitting required reports as MIME attachments.

Recommendations:

- Ensure development of WxV Client includes connectivity with existing shipboard communications system in order to facilitate automated relay of all routine METOC reports

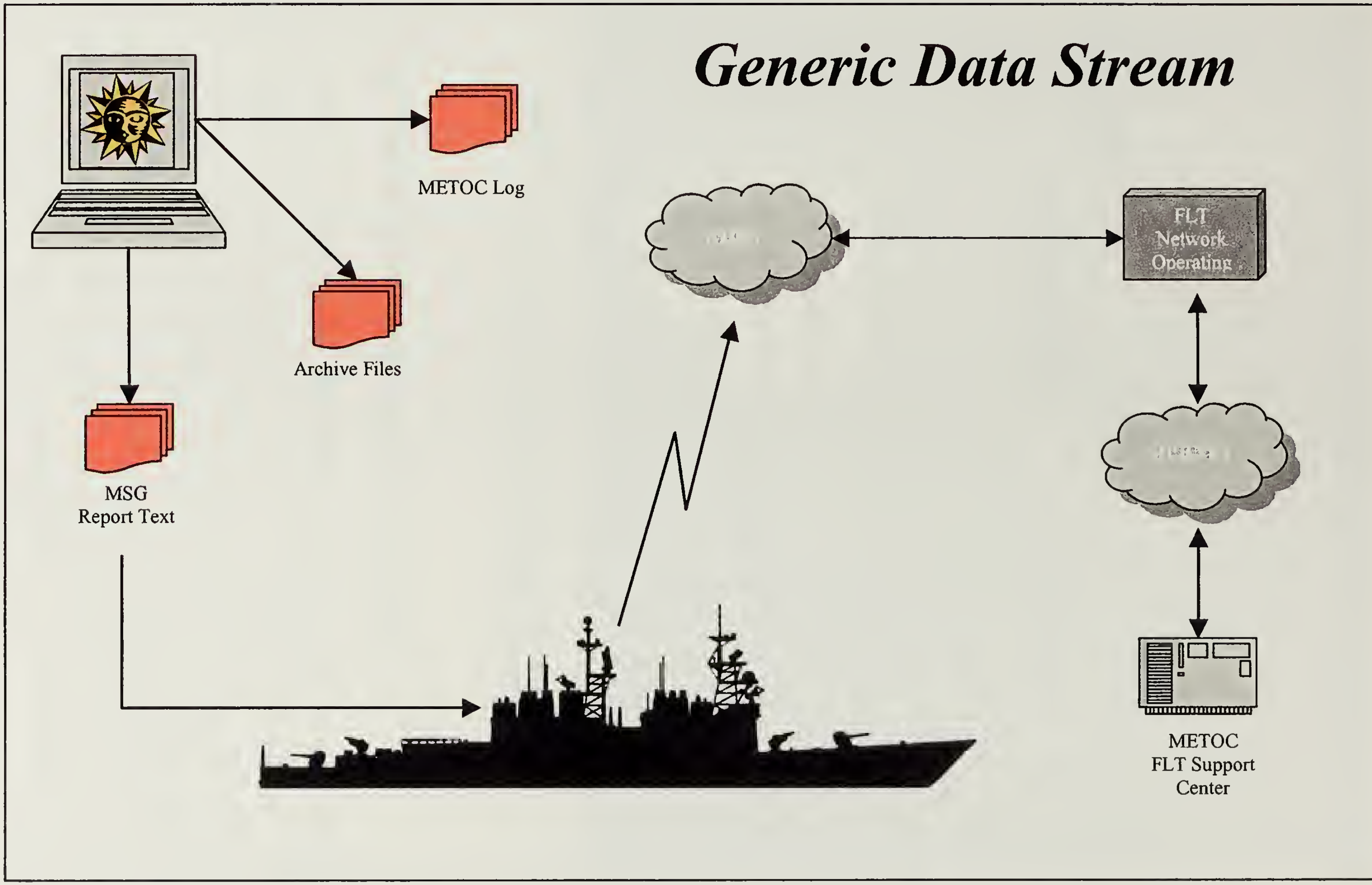

Figure 9-1 Generalized communications architecture for touting METOC observations ashore.

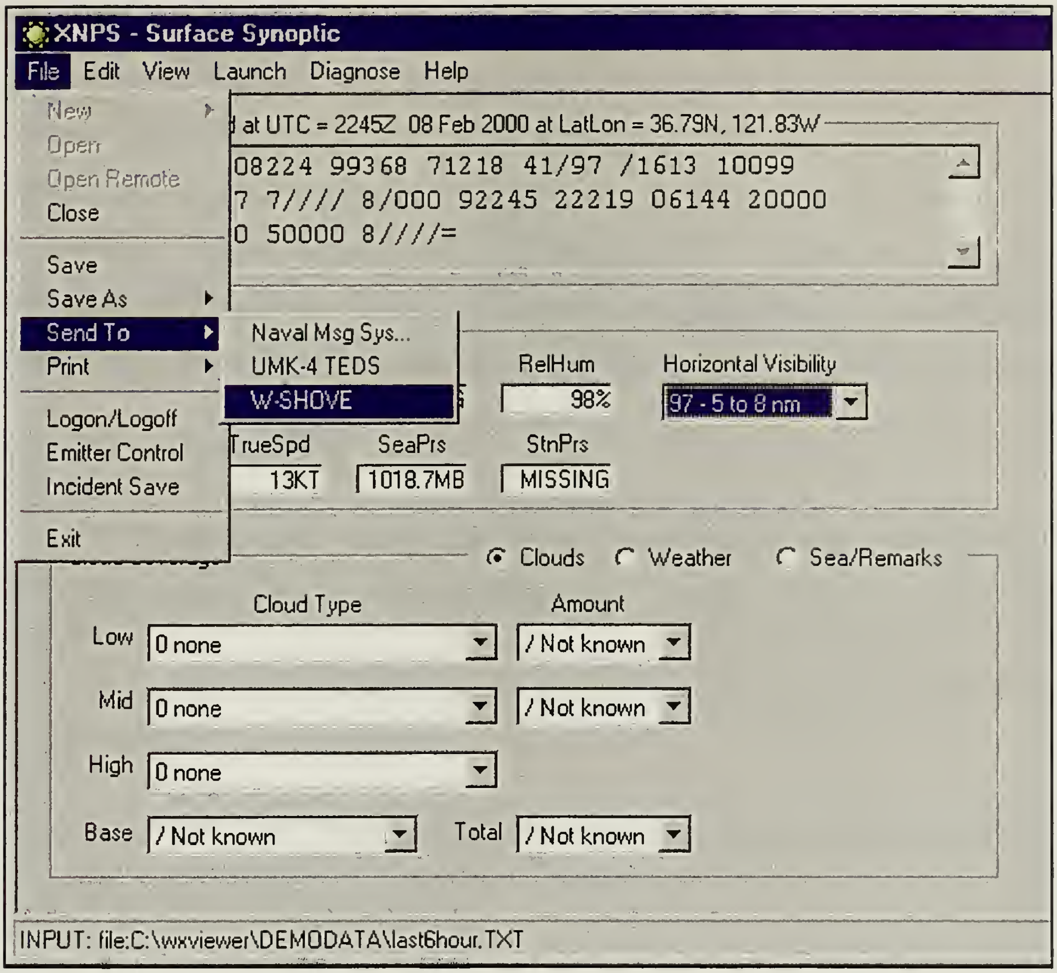

Figure 9-2 WxViewer Client menu functions for transmitting observations via Internet (SIPRNET/NIPRNET).

Issue: Digital METOC data processing for all platforms

232 ships are identified for SMOOS(R) installation with an initial operational capability (IOC) currently planned for FY-01. However, the majority of fleet installations will not occur until after FY-06 (Johnson, 2000). In an effort to introduce digital processing of routine METOC data in the interim, a stand-alone software application similar to WxV Client has been developed and is being submitted to CNMOC for evaluation and recommended distribution to all units required to observe, record and report surface weather conditions. This new application is named Shipboard METOC Archive and ReportTs (SMART) Log. SMART Log performs functions similar to WxV

Client except it does not require automated instrumentation, and it is not supported by a separate server system. Additionally, SMART Log has the potential to support the increased reporting requirements recommended above if communications circuits for relaying such reports at increased frequencies are available. Basic features of SMART Log include: digital logging and encoding of hourly METAR and synoptic surface observations; preparation of daily OTSR reports; automatic archival of all digital records; elimination of paper records; and generation of output files for all reports as .txt files.

Recommendations:

- Conduct beta testing of SMART Log software at NPMOD Pt. Mugu, NLMOD Patuxent River, and NLMOC Norfolk.

- Upon successful beta testing, distribute to all afloat units required to record and transmit METOC observations.

- CNMOC provide funding and assign configuration management and software maintenance to FNMOC.

C. ACQUISITION OF WMO CODED DATA AND OTHER NUMERICAL WEATHER PRODUCTS WHILE UNDERWAY VIA METCAST

The objective here was to demonstrate the value added to on-scene METOC analysis and forecasting through the ability to integrate own-ship reports with other products. METOC impacts our Navy's mission in a myriad of ways, and the fidelity with which we must characterize that impact for our warfighting customers continues to increase (Barbor, 2000).

Implementation of higher resolution models is driving the requirement to make available on-scene METOC observation data at increased frequency from all available sources, as an integral element in the process of forecast evaluation and validation. As discussed above, Figure 8-2 combines multiple analysis and forecast products with on-

scene ship and buoy reports and provides the analyst/forecaster with an immediate visual tool for use in evaluating the accuracy of the analysis and/or forecast products on display.

D. USE OF WMO CODED UPPER AIR REPORTS RETRIEVED VIA METCAST IN TACTICAL DECISTION AIDS

Nearly all TDAs that generate sensor performance predictions rely on METOC data i.e., bathythermograph (ocean temperature vs depth) data for anti-submarine warfare (ASW) sensors, and upper air (atmospheric temperature and humidity vs altitude) data for electromagnetic and electro-optic (EM/EO) systems. The ability to access on-scene (within the immediate area of a battlegroup or independent steaming element) METOC data for use in TDAs is critical toward generating accurate performance information used for planning and execution of real-time warfare missions.

Issue: Availability of sea based upper air data.

In this particular demonstration, the goal was to retrieve on-scene upper air observations for use in AREPS, and generate simulated EM/EO sensor performance predictions. As described above, six upper air reports were successfully transmitted to the METCAST server at FNMOC. However, because METCAST is not configured to decode upper air reports from ships, the data was not made available for retrieval on R/V Pt. Sur. This restricted the use of METCAST to retrieval of shore-based upper air reports from only, and thus prevented AIREPS from ingesting sea-based reports (stored on METCAST servers) directly into the TDA.

Recommendation:

- Minimal modifications to the existing decoder for land station reports (in the METCAST server) are necessary to make sea-based upper air reports available for retrieval (TELCON, 000811) and should be effected at the earliest date possible.

APPENDIX A

Proposed METAR / SPECI Format for Navy Ships

References:
NAVMETOCCOMINST 3141.2
NAVMETOCCOMINST 3144.1D

METAR or **SPECI** $\wedge$ **CCCC** $\wedge$ YYGGgg**Z** $\wedge$ **COR** $\wedge$ dddff(f)G$f_m f_m (f_m)$**KT** $\wedge$ $d_n d_n d_n$**V**$d_x d_x d_x$ $\wedge$ VVVVV**SM** $\wedge$ w'w' $\wedge$ [$N_s N_s N_s h_s h_s h_s$ or **VV**$h_s h_s h_s$ or **SKC**] $\wedge$ T'T'/T'$_d$T'$_d$ $\wedge$ **A**$P_H P_H P_H P_H$ $\wedge$ **RMK** $\wedge$ **PA**$h_A h_A h_A h_A$**FT/ DA**$h_D h_D h_D h_D$**FT** $\wedge$ $T_f T_f$/ $T_{df} T_{df}$ $\wedge$ **RH**qqq $\wedge$ Manual, Plain Language $\wedge$ **8 /** $C_L C_M C_H$ $\wedge$ 5appp $\wedge$ **SLP**ppp $\wedge$ **EDH**hhh**FT** $\wedge$ $L_a L_a L_a$**N-S /** $L_o L_o L_o L_o$**E/W** $\wedge$ **CRS**$D_s D_s D_s$**SPD**$v_s v_s$ $\wedge$ **SST**$T_w T_w T_w$ $\wedge$ **SEA**$P_w P_w H_w H_w$ $\wedge$ **SW1**$d_{w1} d_{w1} P_{w1} P_{w1} H_{w1} H_{w1}$ $\wedge$ **SW2**$d_{w2} d_{w2} P_{w2} H_{w2} H_{w2}$

$\wedge$ = a mandatory space between code groups

METAR or **SPECI** – type of observation

CCCC – station call sign

YYGGgg**Z** - date and time (GMT) of the observation

COR – signifies a corrected observation

dddff(f)**G**$f_m f_m (f_m)$**KT** – wind direction (10's of degrees), wind speed (knots) and wind gusts (knots)

$d_n d_n d_n$**V**$d_x d_x d_x$ – wind direction variability (10's of degrees)

VVVVV**SM** – visibility (whole and fractions of statute miles)

w'w' – present weather contraction(s)

[$N_s N_s N_s h_s h_s h_s$ or VV$h_s h_s h_s$ or SKC] – cloud layer type and height (100's of feet) of cloud layer(s) or vertical visibility (feet) or SKC (sky clear)

T'T'/T'$_d$T'$_d$ – air temperature and dew point temperature (degrees Celsius)

A$P_H P_H P_H P_H$ – altimeter setting (Hg)

RMK – identifier for remarks section

PA$h_Ah_Ah_Ah_A$**FT**– pressure altitude (feet)

DA$h_Dh_Dh_Dh_D$**FT**– density altitude (feet)

T_fT_f / $T_{df}T_{df}$ - air temperature (degrees Fahrenheit) / dew point temperature (degrees Fahrenheit)

RHqqq - relative humidity (percent)

Manual, Plain Language – remarks amplifying any preceding data

8 / $C_LC_MC_H$ – three and six hourly synoptic cloud type

5appp – pressure tendency group, reported for ship's in port or at anchor only

SLPppp – sea level pressure

EDHhhh**FT** – evaporative duct height (feet)

$L_aL_aL_a$**N-S** – latitude (1/10's of degrees

$L_oL_oL_oL_o$**E-W** – longitude (1/10's of degrees)

CRS$D_sD_sD_s$**SPD**v_sv_s – ships course (degrees) and speed (knots)

SST$T_wT_wT_w$ – sea surface temperature (degrees Celsius)

SEA$P_wP_wH_wH_w$ – sea wave period (seconds) and height (feet)

SW1$d_{w1}d_{w1}P_{w1}P_{w1}H_{w1}H_{w1}$ – primary swell wave direction (10's of degrees), period (seconds) and height (feet)

SW2$d_{w2}d_{w2}P_{w2}H_{w2}H_{w2}$ – secondary swell wave direction (10's of degrees), period (seconds) and height (feet)

APPENDIX A (continued)

SAMPLE METAR REPORT

METAR XNPS 290255Z 17027G40KT 260V320 2 1/2 SM SHRA BKN005 OVC015 19/16 A2942 RMK PA467FT/DA1284FT 66/61 RH84 OCNL LTG CC E 8/8// SLP961 EDH018FT 374N/0730W CRS350SPD08 SST14 SEA0405 SW1180404

Explanation: This is a regular METAR report from ship XNPS on the 29th at 0255Z. Winds were from 170 degrees at 27 gusting to 40 knots. Wind direction varied between 260 and 320 degrees. Visibility was 2½ statute miles in light rainshowers. Sky condition was broken at 500ft and overcast at 1500ft. The temperature =19C / 66F and dew point = 16C / 61F. The altimeter setting = 29.42 inches, pressure altitude = 467ft, density altitude =1284ft, and relative humidity = 84%. The low cloud type was cumulus and stratocumulus with bases at different levels (low cloud code 8). Sea level pressure = 996.1 hPa and the evaporative duct height was 18ft. At the time of the observation, the ship was located at 37.4N/073.0W, ships heading was 350 degrees at 08kts. The sea surface temperature = 14C, wind/sea waves were 4 seconds at 5 feet and the primary swell wave was toward 180 degrees with a period of 04 seconds and a height of 04 feet.

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APPENDIX B

SAMPLE ARCHIVE DATA FILE

```
TYPE,DATE,TIME,DIRECTION,SPEED,GUST,VARIABILITY,VISIBILITY,PRESENT WEATHER,SKY CONDITION,TEMP,DEW POINT,WET BULB,ALTIMETER SETTING,REMARKS,STATION
PRESSURE,SEA LEVEL PRESSURE,TOTAL SKY COVER,OBSERVERS INITIALS,SHIPS POSITION,COURSE,SPEED,SEA WATER TEMP,SEA WAVES PD HT,PRI SWELL DIR PD HT,SEC SWELL DIR
PD HT,MISC
ME,26-Mar-00,2355,320,05,,,7,,FEW 080,17.2,04,10.6,979,122/536 63/40 43% 8/030 SLP086,29.72,086,1,GAW,73670732,180,04,21.7,0202,000000,000000,NONE
ME,27-Mar-00,0055,310,07,,,7,,SKC,16.7,05,10.6,981,103/452 62/41 46% SLP094,29.74,094,0,GAW,73660731,180,05,21.7,0202,000000,000000,NONE
ME,27-Mar-00,0155,330,07,,,7,,SKC,18.3,03,10.6,982,94/624 65/38 37% SLP099,29.75,099,0,GAW,73660731,180,04,21.7,0202,000000,000000,NONE
ME,27-Mar-00,0255,240,07,,,7,,SKC,18.3,03,10.6,983,84/612 65/38 37% 8/000 SLP102,29.76,102,0,GAW,73660730,140,14,20.6,0202,000000,000000,NONE
ME,27-Mar-00,0355,260,10,,,7,,SKC,17.8,02,10.0,983,84/540 64/36 35% SLP102,29.76,102,0,KTT,73640728,180,15,20.6,0202,000000,000000,NONE
ME,27-Mar-00,0455,260,11,,,7,,SKC,18.3,03,10.6,983,84/612 65/38 37% SPL102,29.75,102,0,KTT,73601728,180,15,20.6,0202,000000,000000,NONE
ME,27-Mar-00,0555,250,14,,,7,,FEW 030,19.4,03,11.1,981,103/764 67/38 34% 8/200 SLP095,29.74,095,2,KTT,73601728,180,10,17.2,0202,000000,000000,NONE
ME,27-Mar-00,0655,270,06,,,7,,SKC,19.4,06,12.2,979,122/808 67/49 42% SLP 088,29.72,088,0,KTT,73610729,270,14,17.2,0202,000000,000000,NONE
ME,27-Mar-00,0755,220,07,,,7,,FEW 065,19.4,08,12.8,977,140/846 67/46 47% SLP 082,29.7,082,1,KTT,73630731,075,04,17.2,0202,000000,000000,NONE
ME,27-Mar-00,0855,270,03,,,7,,FEW 010,19.4,08,12.8,978,131/834 67/46 47% 8/100 SLP082,29.71,082,2,KTT,73640730,350,15,21.1,0202,000000,000000,NONE
ME,27-Mar-00,0955,190,09,,,7,,FEW 010 SCT 100,19.4,08,13.3,979,122/823 67/46 47% SLP087,29.72,087,3,KTT,73640729,340,11,21.1,0202,000000,000000,NONE
ME,27-Mar-00,1055,190,09,,,7,,FEW 010 FEW100 SCT 120,19.4,10,13.9,978,131/856 67/50 54% SLP085,29.71,085,3,KTT,73640730,270,05,21.1,0202,000000,000000,NONE
ME,27-Mar-00,1155,150,13,,,7,,FEW 015 FEW100 SCT180,19.4,12,15.0,977,140/893 67/54 63% 8/131
SLP081,29.7,081,3,ARB,73640730,230,05,21.1,0202,000000,000000,NONE
ME,27-Mar-00,1255,170,19,,,7,,FEW020 SCT100 SCT180,19.4,12,15.0,977,140/893 67/54 63% SLP080,29.7,080,4,ARB,73640731,230,05,20.6,0203,000000,000000,NONE
ME,27-Mar-00,1355,160,23,,,7,,BKN 020CB BKN 200,20.0,13,15.6,976,149/975 68/55 63% CB W MOV NE VC SHRA
SLP079,29.7,079,7,ARB,73640731,230,04,20.6,0203,000000,000000,NONE
ME,27-Mar-00,1455,200,04,,,7,,BKN 020CB BKN 200,20.0,15,16.7,975,159/1016 68/59 73% CB NW MOV NE VC SHRA 8/301
SLP072,29.67,072,7,KMS,73640731,100,04,20.6,0203,000000,000000,NONE
ME,27-Mar-00,1555,180,26,,,7,,SCT020 BKN100 BKN200,20.0,15,16.7,976,149/1004 68/59 73% SLP078,29.69,078,7,ARB,73640731,220,04,20.6,0304,180302,000000,NONE
ME,27-Mar-00,1655,180,26,,,7,,SCT050 BKN100,21.1,15,17.2,974,168/1155 70/59 68% SLP070,29.67,070,6,ARB,73640731,355,05,22.8,0304,180303,000000,NONE
ME,27-Mar-00,1755,180,24,,,7,,SCT050 BKN100 OVC200,21.1,15,17.2,971,196/1190 70/59 68% 8/167
SLP061,29.64,061,8,ARB,73660731,355,09,22.8,0405,180303,000000,NONE
ME,27-Mar-00,1855,160,28,,,7,,FEW 020 FEW050 BKN100 BKN200,21.1,15,17.2,968,224/1224 70/59 68%
SLP049,29.6,049,7,ARB,73680729,355,10,22.8,0405,180303,000000,NONE
ME,27-Mar-00,1955,180,29,,,7,,FEW020 FEW050 SCT100 BKN200,20.6,08,13.3,964,261/1124 69/46 44%
SLP036,29.57,036,7,BKW,73710729,355,10,22.8,0405,180303,000000,NONE
ME,27-Mar-00,2055,160,34,,,7,,FEW020 FEW050 SCT100 BKN200,20.6,08,13.3,962,280/1147 69/46 44% 8/131
SLP031,29.55,031,7,BKW,73710729,210,03,22.8,0404,180303,000000,NONE
ME,27-Mar-00,2155,180,29,,,7,,SCT020 SCT050 BKN100 OVC200,19.4,11,14.4,959,308/1086 67/52
56%SLP019,29.52,019,8,BKW,73710729,210,02,22.8,0404,180303,000000,NONE
SP,27-Mar-00,2225,160,27,,,7,,BKN020 BKN050 BKN100,,,,957,326/1110,29.5,,,BKW,73710730,270,00,22.8,,,,NONE
ME,27-Mar-00,2255,160,35,,,7,,BKN020 BKN050 BKN100,19.4,13,15.6,956,336/1170 67/56 68% SLP013,29.49,013,7,BKW,73170729,210,01,14.4,0405,180303,000000,NONE
ME,27-Mar-00,2355,160,34,,,7,,BKN020 OVC050,19.4,13,15.6,953,364/1182 67/56 68% 8/811 SPL001,29.47,001,8,BKW,73710729,360,04,14.4,0404,180404,000000,NONE
ME,28-Mar-00,0055,160,30,,,7,,BKN020 OVC050,19.4,13,15.6,950,392/1217 67/56 68% SPL991,29.44,991,8,BKW,73720729,360,04,14.4,0404,180404,000000,NONE
ME,28-Mar-00,0155,160,36,,,3,SHRA,OVC 020,19.4,16,17.2,947,420/1290 67/61 81% OCNL LTG CC E
SLP981,29.4,981,8,BKW,73740729,360,09,14.4,0404,180404,000000,NONE
ME,28-Mar-00,0255,170,27,,,4,SHRA,OVC 020,18.9,16,17.2,942,467/1284 66/61 84% OCNL LTG CC E 8/211
SLP961,29.37,961,8,BKW,73740730,350,08,13.9,0405,180404,000000,NONE
ME,28-Mar-00,0355,170,30,,,4,SHRA,OVC 020,17.2,16,16.1,939,495/1116 63/60 90% SLP951,29.32,951,8,RAM,73770730,220,07,13.9,0405,180404,000000,NONE
ME,28-Mar-00,0455,170,40,,,4,SHRA,OVC 020,17.8,16,16.7,932,561/1271 64/61 90% DSNT LTG W SLP992,29.25,992,8,RAM,73750732,220,06,13.9,0405,180404,000000,NONE
ME,28-Mar-00,0555,180,34,,,4,SHRA,OVC 020,15.6,16,15.6,934,542/979 60/60 100% 8/211 SLP993,29.35,993,8,RAM,73750732,190,07,11.7,0405,180404,000000,NONE
ME,28-Mar-00,0655,210,20,,,4,SHRA,FEW010 OVC020,15.6,16,15.6,924,636/1096 60/60 100% DSNT LTG E
SLP990,29.17,990,8,RAM,73750733,190,11,11.7,0405,180404,000000,NONE
SP,28-Mar-00,0720,210,23,,,5,BR,FEW 010 BKN020 ,,,,927,DSNT LTG E,,,,RAM,73720733,190,13,11.7,,,,NONE
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APPENDIX C

LIST OF ACRONYMS

ADNS............Automated Digital Network System

AG............Aerographers Mate

ALRE............Aircraft Launch and Recovery Equipment

ANZ............USS Anzio

AREPS............Advanced Refractive Effects Prediction System

C4I............Command, Control, Communications, Computers and Intelligence

CINCPAC............Commander in Chief, U.S. Pacific

CNMOC............Commander, Naval Meteorology and Oceanography Command

CNO............Chief of Naval Operations

COTS............Commercial-Off-The-Shelf

CSG............USS Capt St. George

CSI............Campbell Scientific, Inc.

EDH............Evaporative Duct Height

ESM............Electronic Support Measures

FNMOC............Fleet Numerical Meteorology and Oceanography Center

FNMOD............Fleet Numerical Meteorology and Oceanography Detachement

GPS............Geostationary Positioning System

GUI............Graphical User Interface

HTTP............Hypertext Transfer Protocol

LIST OF ACRONYMS (continued)

I/O .... Input/Output

JHU-APL .... Johns Hopkins University – Applied Physics Laboratory

JMV .... Joint METOC Viewer

MET .... Mobile Environmental Team

METOC .... Meteorology and Oceanography

MIME .... Multipurpose Internet Mail Extension

NAVAIRSYSCOM .... Naval Air Systems Command

NAVMETOCCOMINST .... Naval METOC Command Instruction

NDWMIS .... New Digital Wind Measuring and Indicating System

NIPRNET .... Non-secure IP (Internet Protocol) Router Network

NOC .... Network Operating Center

NPS .... Naval Postgraduate School

NRL-MRY .... Naval Research Laboratory-Monterey

NWP .... Numerical Weather Prediction

OPAREA .... Operations Area

ORD .... Operational Requirements Document

OTC .... Officer in Tactical Command

OTSR .... Optimum Track Ship Routing

NOC .... Network Operating Center

SCIMS .... Surface Combatant In-Situ METOC System

SHF .... Super High Frequency

LIST OF ACRONYMS (continued)

SIPRNET .... Secret IP (Internet Protocol) Router Network

SMOOS........................Shipboard Meteorological and Oceanographic Observation System

SMOOS(R) ....SMOOS Replacement

SOPA ....Senior Officer Present Ashore

SPAWARSYSCOM ....Space and Naval Warfare Systems Command

TAD-SC ....Theatre Air Defense-Surface Combatants

TDA .... Tactical Decision Aid

TEDS ....Tactical Environmental Data Server

UHF .... Ultra High Frequency

VHF .... Very High Frequency

WMO .... World Meteorological Organization

WxV...Weather Viewer

XML...Extended Mark-up Language

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